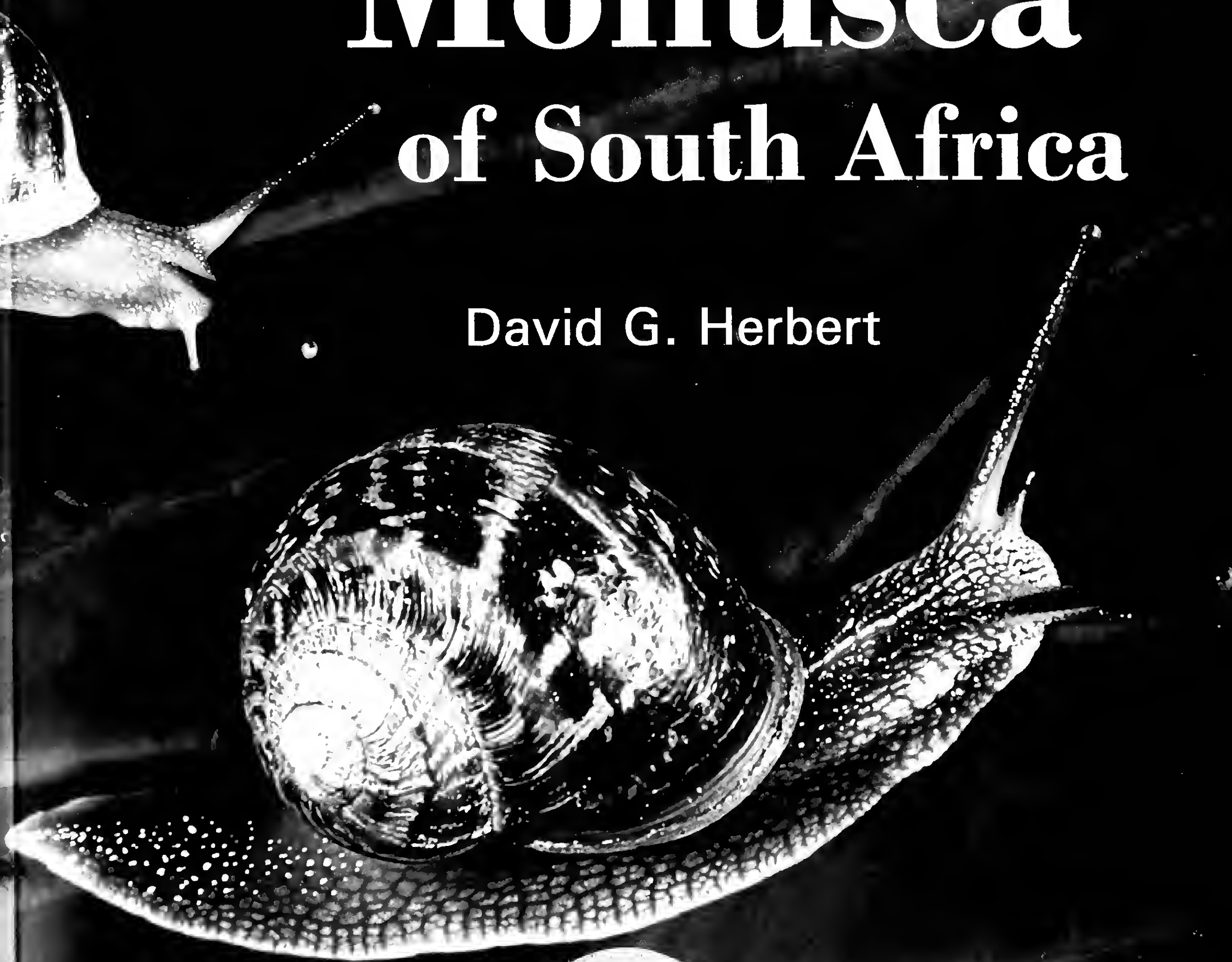
The introduced terrestrial Mollusca of South Africa

David G. Herbert



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The introduced terrestrial Mollusca of South Africa

by

David G. Herbert

SOUTH AFRICAN
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SANBI Biodiversity Series

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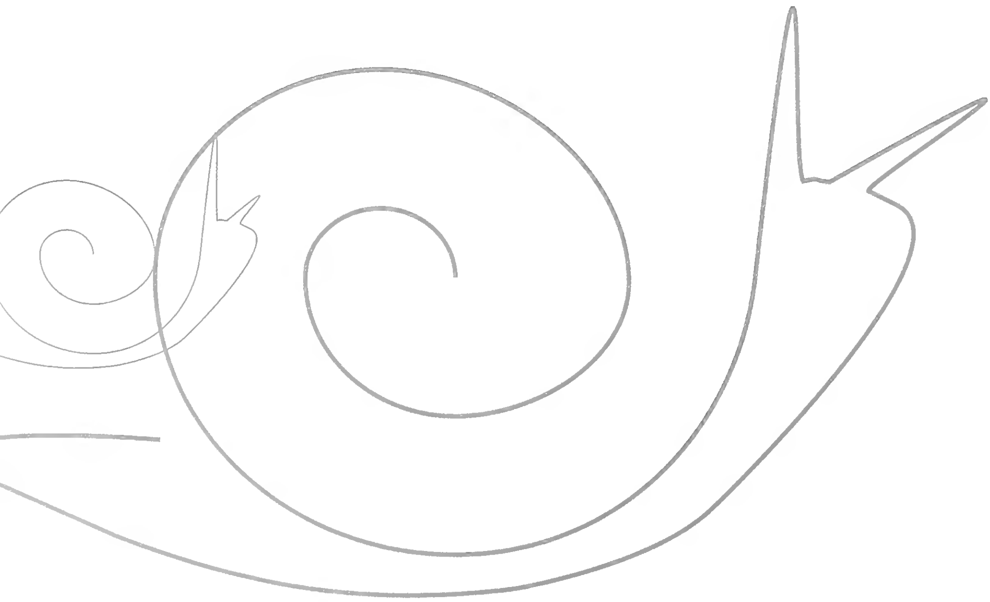
Contents

A plea for assistance from a rather desperate member of the public concerning *Theba pisana*.

'Dear Dr Herbert

I recall in a copy of *Veld and Flora* some 18 months ago you asked for help in a snail survey. Well, I am asking for HELP with eradicating snails (those horrible little white ones) which have become such a huge pest in my garden that after many years of trying EVERY remedy on Earth, they have actually multiplied tenfold instead of decreasing! I am truly at my wits end! I don't have a garden left and they seem to love the harsh West Coast climate - they don't mind the hot, dry summers or the cold, wet winters! Even the birds are tired of eating them! ANY help will be greatly appreciated.'

Saldanha Bay, 11/iv/2002



Abstract

The alien terrestrial mollusc fauna of South Africa is comprehensively reviewed. 34 species are considered to have been introduced to the country, of which 28 are considered established and 13 of these invasive. The history of introduction and recording is summarised and patterns of introduction are analysed. Introductions continue at a rate of approximately two species per ten years, with no evidence of levelling off. The agriculture and horticulture industries are considered to be major contributors to the introduction and spread of alien species. The composition of this alien fauna shows considerable similarity with that known from southern Australia, reflecting the similar colonial history of the regions and climatic matching with regions of origin in western Europe and the Mediterranean. Each species is discussed in terms of its distinguishing features, habitat preferences, date of introduction and first record, native range and global distribution, distribution in South Africa, pest status, and similarity with indigenous species. Further taxonomic notes and biological observations relating to behaviour, reproduction and parasite transmission are included where relevant, and references to sources of additional information are provided. In addition, some consideration is given to potentially pestiferous species which are not yet known to occur in South Africa, but which represent a significant future introduction risk. New records: *Discus rotundatus*, *Hawaiia minuscula*, *Vitrea contracta*, *Aegopinella nitidula*.

Acknowledgements

I am grateful to: Dr Willem Sirgel (University of Stellenbosch) for sharing additional information regarding distribution records and for commenting on the manuscript; the Wildlife and Environment Society of South Africa for facilitating my 'Snailiens' project and the many South African teachers and schools that participated in the data collection; Prof. Thierry Backeljau for identifying arionid slugs; Drs Geof Baker, Suzanne Charwat and Angela Lush (South Australian Research and Development Institute) for providing insight into the alien mollusc problems in Australia; Mary Cole and Linda Davis for assistance with field survey work; Dr David Robinson (UDSA, APHIS) for information and his ongoing interest in this project; Ben Rowson (National Museum of Wales) for assistance with photographs and literature queries. As always, I am also much indebted to Linda Davis for converting my *camera lucida* drawings of genital anatomy into scientific illustrations of high quality. I also acknowledge the University of KwaZulu-Natal for use of automontage facilities at its Centre for Electron Microscopy. Lastly, but by no means least, I thank Gerrit Germishuizen for his meticulous technical editing and Sandra Turck for the design and layout.

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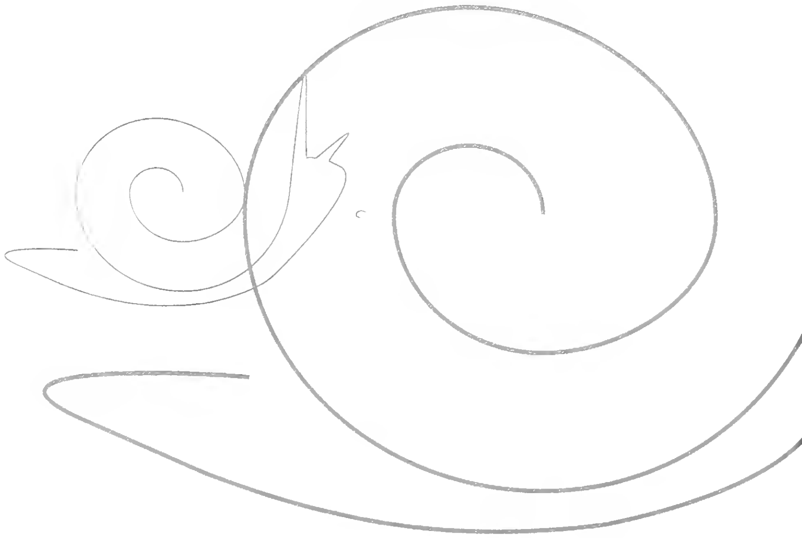


Introduction

Aliens species, particularly those that become invasive, have enormous economic and environmental consequences. Pimentel *et al.* (2005) estimated annual economic costs of approximately US$120 billion resulting from invasive alien species in the USA alone. Biodiversity costs may also be considerable and introduced species are recognised as one of the most significant threats facing Earth's biota (Clout 1995, 2002), resulting in the homogenisation of once diverse faunas (McKinney & Lockwood 1999; Cowie 2004). The economic impact of many terrestrial snail and slug pests in the agriculture sector is well known (Barker 2002a), and instances where introduced freshwater molluscs have resulted in high economic costs include zebra and quagga mussels (*Dreissena* spp.) and the Asian clam (*Corbicula fluminea*) in North America (Pimentel *et al.* 2000), and apple snails (*Pomacea* spp.) in Hawaii and Southeast Asia (Cowie 2002).

For terrestrial species, these economic costs may relate to direct impacts of the molluscs themselves, such as their feeding, faecal and mucus soiling of crops, and clogging of harvesting machinery. Alternatively, costs may be associated with indirect impacts or downstream consequences such as the transmission of parasites and diseases, the contamination of produce leading to its down-grading at point of sale or rejection by quarantine officials at ports of entry, and rejection of snail-infested pasture by livestock (Baker 2002). Many terrestrial gastropods are known to serve as intermediate hosts to economically important livestock parasites, particularly platyhelminths and nematodes (South 1992; Boray & Munro 1998; Godan 1999; Otranto & Traversa 2002; Grewal *et al.* 2003; Morand *et al.* 2004), some of which may also affect humans (Kliks & Palumbo 1992; Spratt 2005), and to function as vectors of crop plant pathogens (Mead 1961; Godan 1983; South 1992; Boray & Munro 1998; El-Hamalawi & Menge 1996; Alvarez *et al.* 2009). Less obvious indirect costs, resulting for example from changes in tilling/burning regimes aimed at snail control, may include increased soil erosion and lowered levels of organic matter entering the soil, leading to altered nutrient cycling processes (Baker 2002). In terms of biodiversity costs, the impact of the rosy wolf snail (*Euglandina rosea*) on the native snail fauna of islands in the south Pacific is now widely viewed as a worst case scenario resulting from ill-conceived biological control initiatives (Civeyrel & Simberloff 1996; Coote & Loéve 2003; Lydeard *et al.* 2004). Six species of mollusc are listed amongst the top 100 worst invasive alien species in the world (IUCN–ISSG 2000).

Land snails and slugs are undoubtedly adept hitchhikers and, with human assistance, many species have now become widely distributed across the globe (Smith 1989; Robinson 1999). Evidence from archaeological investigations indicates that ship-mediated translocation of land snails is a process of some antiquity, with one Mediterranean example dating from 3 300 years BP (Late Bronze Age) (Welter-Schultes 2008), another perhaps 5 000 years BP (Giokas *et al.* 2009). DNA data also suggest that ancient trade routes have been important in the dispersal of snails within the Mediterranean (Fiorentino *et al.* 2008 and references therein).

The introduction of land snails to South Africa almost certainly began with the arrival of the European colonists in the late 1600s and early 1700s. In order to survive in an essentially unknown land, these early settlers must frequently have brought familiar crop plants with them. These they knew how to cultivate and they could therefore guarantee a food supply in their new but unfamiliar home. Jan van Riebeeck, for example, is known to have imported vine cuttings (wrapped in moist soil) to the Cape as early as the 1650s (Hughes *et al.* 1992) and in 1652 he established the Dutch East India Company gardens as a victualling station in what is now Cape Town (McCraken & McCraken 1988). As the colony grew, subsequent settlers imported ornamental flowers, shrubs and

trees to grow in their gardens. Later still, in the mid to late 1800s, formal botanical gardens with a wide variety of non-native plants were established in a number of towns (McCracken & McCracken 1988). This imported horticultural stock almost certainly did not come alone. The plants were often rooted in containers, in which the soil would undoubtedly have contained a range of invertebrates, either as adults or as eggs, and plant pathogens from their original homes. No doubt many of these failed to establish viable populations in their new environment, but others have, to varying degrees, been able to exploit this opportunity to their own advantage. The periodic introduction of non-indigenous species is now an ongoing phenomenon and likely to occur with increased frequency as globalised trade expands. Westphal *et al.* (2008) have shown that the greater the degree of international trade, the higher the number of invasive alien species. Given that many terrestrial gastropods are pests of commercially important crops, disease vectors and competitively efficient colonisers of native habitats, it is important that we take stock of how far this process has progressed, monitor the spread of those species already introduced, identify new introductions at an early stage, be alert to the possibility of the introduction of further tramp species, particularly those of economic significance, and implement effective measures so as to minimise the risk of further introductions.

The total number of confirmed introductions of non-native terrestrial molluscs in South Africa now stands at 34, of which 28 appear to have established self-sustaining populations. However, although some were undoubtedly introduced in the 1600s and 1700s, our knowledge of them dates only from the first studies of the South African malacofauna, which essentially began in the mid-1800s. The earliest record of an introduced snail in South Africa dates from 1846 when William Benson, on a visit to Cape Town, collected *Oxychilus cellarius* and *Vallonia pulchella* (Benson 1850) [despite being on crutches]. By this time, the common European garden snail, *Cornu aspersum*, was also probably well established, even though the first confirmed record for the species dates only from 1855. With a growing population and increasing trade, the accidental importation of alien molluscs has continued, with discoveries of new introductions being made on a regular basis.

Many molluscan colonists are species that thrive in association with humans (synanthropic); indeed it is largely because of this habit that they are such effective globe-trotters. Deprived of their natural predators and with the opportunity to exploit unoccupied ecological niches, many introduced species have faired extremely well in parts of South Africa where the climate is favourable—to such an extent that they now constitute significant pests, particularly for gardeners and crop growers. Alien snails and slugs generally present far more of a problem than do the indigenous species, which co-exist in a long-established balance with their natural competitors, predators and diseases. No data are available regarding the economic costs of alien pest snails and slugs in South Africa, but Pimentel (2002) estimated crop loss and control costs for alien invertebrate pests in South Africa to be US$1 billion per annum. In 1989, Boray & Munro (1998) estimated that in Australia, which has a similar alien gastropod fauna and similar climatic regimes, the cost of damage caused by terrestrial molluscs amounted to at least A$50 million per annum, most of which is caused by the alien species. They further estimated that A$10 million was spent per annum on chemical control of snails in Australian domestic gardens alone.

Fortunately, some of the most pestiferous introduced terrestrial gastropods in South Africa (e.g. *Cornu aspersum*) have not been able to spread extensively into natural environments and, though often widely distributed, are more or less restricted to gardens, monoculture plantations and transformed habitats in general. However, assisted by humans, others, such as the field slugs of the genus *Deroceras*, have spread beyond transformed environments, even into relatively pristine natural habitats. In the dry, Mediterranean areas of the western Cape the white garden snail or dune snail, *Theba pisana*, is so abundant in places that herbaceous plants, low growing shrubs and fence-posts can be festooned with thousands of aestivating snails. Although the extent of the damage done by these snails has not been quantified (and to do so is not a simple task), it undoubtedly represents a cause for concern (Odendaal *et al.* 2008).

To date the information available on the South African alien terrestrial molluscan fauna is fragmented and mostly restricted to specialist malacological literature, and has focused primarily on taxonomic issues and recording. The most recent review was that of Van Bruggen (1964). Brief mention of pestiferous species may be found in the agricultural literature (Gunn 1924; Dürr 1946; Joubert & Walters 1951; Swart *et al.* 1976; Bedford 1978; Myburgh 1986–90; Schwartz 1988; Ferreira & Venter 1996; Joubert & Du Toit 1998; De Jager & Daneel 2002), but the review literature pertaining to the alien and invasive biota of South Africa has made limited reference to terrestrial molluscs (Macdonald *et al.* 1986; Richardson *et al.* 2000a; Zimmermann 2003), even that discussing alien invertebrates (Lach *et al.* 2002). The purpose of this review is therefore to collate the existing information and a substantial amount of unpublished data, so as to provide an up-to-date and comprehensive reference resource on the alien terrestrial mollusc fauna of South Africa. In so doing, I draw attention to issues of concern in the hope that this will stimulate further research on the environmental and economic significance of the principal villains. The alien freshwater mollusc fauna of South Africa has been recently reviewed by Appleton (2003).

The 34 alien terrestrial gastropods so far recorded in South Africa represent a subset of a global pool of taxa recognised as travelling snails (including slugs) by Smith (1989). Smith's original list cited 59 species (including freshwater species), but Robinson (1999) added further species, bringing the total to 163, and noted that the list would undoubtedly continue to grow. Out of the 34 confirmed snail and slug introductions in South Africa, 33 are included in this list. Only *Aegopinella nitidula* is not included. Of the total of 34 for South Africa, 25 are shared with Australia (Smith 1992), 19 with New Zealand (Barker 1999) and 15 with Hawaii (Cowie 1997, 1999). That Australia and New Zealand should share a significant number of alien species with South Africa is unsurprising, given the similar colonial history of these regions, and that Australia should share the highest number is likewise expected in view of the fact that many regions in southern Australia experience a climate similar to that of South Africa and Mediterranean Europe.

Information pertaining to the alien terrestrial mollusc fauna of neighbouring countries within southern Africa is fragmentary or non-existent. To date the limited data available suggests that that five to six species have been reliably recorded from Namibia, four from Zimbabwe, two from Lesotho and one each from Mozambique and Swaziland. Undoubtedly these figures under-represent the true number.

Materials and Methods

The bulk of the material discussed in this study is deposited in the Natal Museum in Pietermaritzburg. This material has been accumulated over more than 100 years, but a more intensive programme targeting alien terrestrial molluscs was initiated in the mid-1990s. Until then, although new discoveries of alien species were occasionally recorded, survey work on South Africa's terrestrial molluscs focused on the indigenous taxa, whereas alien species were frequently ignored. Spatial data regarding the distribution and spread of alien species were therefore limited. A significant amount of additional distribution data was gathered between 2000 and 2002 via an environmental education project ('Snailiens') initiated by the author and facilitated by the Wildlife Society and Environment of South Africa. Further records were obtained from the published literature and all data were entered into the Natal Museum Mollusca database. Any records of dubious validity or specimens with questionable provenance were excluded. Distribution maps were drawn using ArcView GIS software [ESRI].

References cited in synonymy include only the original descriptions and those referring to the species concerned in a South African context. The full synonymies are often extensive and can be found in the literature pertaining to the region of origin of the taxa concerned. All species recorded from the country were included in the quantitative assessments, even those not established or which have been eradicated. However, two species for which there is uncertainty about the identification (*Vertigo antivertigo* and *Cecilioides acicula*) were excluded. Where a species was recorded but did not become established and was subsequently re-introduced, the date of the first record was used. For the purposes of definition, a taxon is considered established (naturalised) when it is thought that the population(s) is regularly reproducing and of a sufficiently large size that the likelihood of extinction due to natural environmental stochasticity is low. It is considered invasive if it has spread beyond transformed landscapes into disturbed, semi-natural habitats and pristine habitats (Richardson *et al.* 2000b).

Abbreviations

ICZN	–	International Code of Zoological Nomenclature
IUCN–ISSG	–	IUCN Invasive Species Specialist Group.
NMSA	–	Natal Museum, Pietermaritzburg, South Africa.
NMW	–	National Museum of Wales, Cardiff, UK.
SA	–	South Africa.
USDA	–	United States Department of Agriculture

Species		Family	Introduction	First record	Status
1.	*Achatina fulica**	Achatinidae	pre 1900	Connolly, 1912	Not established
2.	*Deroeeras laeve**	Agriolimacidae	pre 1898	Sturany, 1898	Established, invasive
3.	*Deroceras panormitanum**	Agriolimacidae	pre 1963	Van Bruggen, 1964	Established, invasive
4.	*Deroceras reticulatum**	Agriolimacidae	pre 1898	Melvill & Ponsonby, 1898	Established, invasive
5.	*Arion hortensis* aggr.*	Arionidae	pre 1939	Connolly, 1939	Established, locally invasive
6.	*Arion intermedius**	Arionidae	pre 1898	Collinge, 1900	Established, locally invasive
7.	*Bradybaena similaris**	Bradybaenidae	pre 1858	Melvill & Ponsonby, 1898	Established, synanthropic
8.	*Coehlicella barbara**	Cochlicellidae	pre 1909	Connolly, 1912	Established, invasive
9.	*Cochlicopa* cf. *lubrica**	Cochlicopidae	pre 1978	Van Bruggen, 1980	Established, synanthropic
10.	*Cochlieopa* cf. *lubricella**	Cochlicopidae	pre 1965	Van Bruggen, 1967	Established, synanthropic
11.	*Discus rotundatus**	Discidae	pre 1986	new record	Established, locally invasive
12.	*Milax gagates**	Milacidae	pre 1873	Smith, 1884	Established, synanthropic
13.	*Zonitoides arboreus**	Gastrodontidae	pre 1898	Melvill & Ponsonby, 1898	Established, locally invasive
14.	*Cornu aspersum**	Helicidae	pre 1855	Gibbons, 1878	Established, largely synanthropic
15.	*Eobania vermiculata**	Helicidae	pre 1987	Sacchi, 1996	Established, largely synanthropic
16.	*Otala punctata**	Helicidae	pre 1986	Herbert & Sirgel, 2001	Eradicated
17.	*Theba pisana**	Helicidae	pre 1881	Melvill & Ponsonby, 1898	Established, invasive
18.	*Lauria eylindracea**	Lauriidae	pre 1879	Gibbons, 1879	Established, locally invasive
19.	*Lehmannia nyctelia**	Limacidae	pre 1939	Connolly, 1939	Established, largely synanthropic
20.	*Lehmannia valentiana**	Limacidae	pre 1961	Waldén, 1962	Established, largely synanthropic
21.	*Limacus flavus**	Limacidae	pre 1898	Melvill & Ponsonby, 1898	Established, synanthropic
22.	*Limax maximus**	Limacidae	pre 1898	Melvill & Ponsonby, 1898	Established, locally invasive
23.	*Aegopinella nitidula*	Oxychilidae	pre 1930	new record	Uncertain
24.	*Oxychilus alliarius**	Oxychilidae	pre 1894	Connolly, 1912	Established, largely synanthropic
25.	*Oxychilus cellarius**	Oxychilidae	pre 1846	Benson, 1850	Established, largely synanthropic
26.	*Oxychilus draparnaudi**	Oxychilidae	pre 1908	Connolly, 1912	Established, locally invasive
27.	*Hawaiia minuscula**	Pristilomatidae	pre 2006	new record	Established, synanthropic
28.	*Vitrea eontraeta**	Pristilomatidae	pre 2004	new record	Established, locally invasive
29.	*Vitrea crystallina**	Pristilomatidae	pre 1898	Melvill & Ponsonby, 1898	Uncertain
30.	*Rumina decollata**	Subulinidae	pre 1897	Melvill & Ponsonby, 1898	Eradicated
31.	*Subulina octona**	Subulinidae	pre 1913	Germain, 1920	Probably not established in SA
32.	*Testacella maugei**	Testacellidae	pre 1893	Melvill & Ponsonby, 1898	Established, synanthropic
33.	*Vallonia costata**	Valloniidae	pre 1980	Gerber, 1996	Established, synanthropic
34.	*Vallonia pulchella**	Valloniidae	pre 1846	Benson, 1850	Established, synanthropic
Dubious records					
1.	*Cecilioides acicula**	Ferussaciidae	1898	Melvill & Ponsonby, 1898	Not established, record dubious
2.	*Vertigo antivertigo*	Vertiginidae	subfossil	Connolly, 1939	Not established, record dubious

Table 1.—Date of introduction (or first record) of alien terrestrial molluscs in South Africa and their current status. * = recognised travelling species (cf. Robinson 1999)

Theba pisana (Müller, 1774), crawling animal, Cape Agulhas (NMSA V7750 [2000]).

Eobania vermiculata (Müller, 1774), South End cemetery, Port Elizabeth (NMSA V8627 [2000]).

Cochlicella barbara (Linnaeus, 1758), Constantia, Cape Peninsula (NMSA V8326 [2000]).

Cornu aspersum (Müller, 1774), scalariform freak, Cape Town, W. Cape (NMSA V7391 [1999]).

Oxychilus draparnaudi (Beck, 1837), Kirstenbosch, Cape Peninsula (NMSA W5705 [2007]).

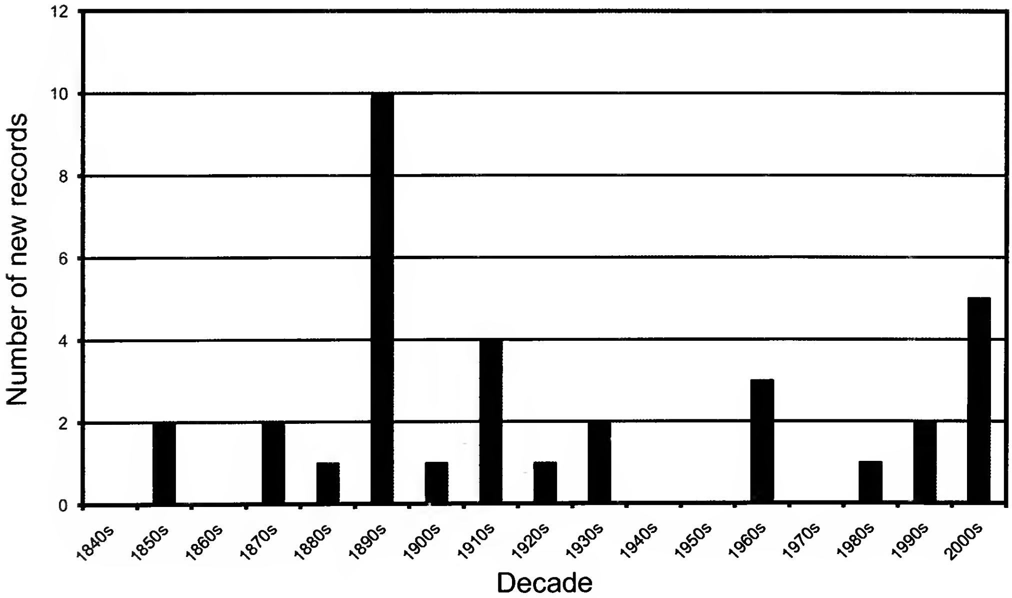
History

The documentation of the South African terrestrial molluscan fauna essentially began with the publication of Ferdinand Krauss' *Die südafrikanischen Mollusken* (Krauss 1848). In this work, however, Krauss included no species now considered to be introduced to the South African fauna. The first confirmed records of alien snails were those of Benson (1950), collected in 1846 in the environs of Cape Town. Additional isolated records appeared during the 1870s and 1880s, published by Gibbons (1878, 1879) and Smith (1884). Subsequently, in 1898, Melvill & Ponsonby provided the first listing of South African non-indigenous terrestrial molluscs adding nine of the ten new records for the 1890s. Later, Connolly included introduced species in his *A revised reference list of South African non-marine Mollusca* (Connolly 1912), treating these in greater detail in a follow-up paper discussing only introduced species (Connolly 1916). He further augmented the known fauna of introduced species in his 1939 monograph (Connolly 1939), and in total contributed six of the eight new records added to the list between 1900 and 1940.

A hiatus in malacological endeavour in South Africa during and after World War II resulted in no new records until the tenure of A.C. van Bruggen as malacologist at the Natal Museum in the early 1960s. Through his own subsequent research and that of malacologists to whom he sent material, an additional four alien species were recorded between 1960 and 1990. Two further isolated records appeared in the 1990s. Since 2000, however, research undertaken by W. Sirgel (University of Stellenbosch) and during the course of the present study, has resulted in a further five new records, four published herein. This history is depicted graphically in Figure 1; the contribution of Melvill & Ponsonby (1898), representing the first formal listing of South Africa's alien slugs and snails, stands out as a singular contribution. However, this data is more reflective of malacological effort and date of detection, rather than the rate of introduction (discussed below), since many published records appreciably post-date the actual date of introduction.

It is curious to note that of the 34 alien terrestrial molluscs recorded to date from South Africa, only one, *Lauria cylindracea*, was described as a new native species, namely *Pupa tabularis* Melvill & Ponsonby, 1893. This is in contrast to Australia, New Zealand and Hawaii, where many species now know to be aliens were initially described as new indigenous taxa (Smith 1992; Barker 1999; Cowie 1999). If undetected, such pseudoindigenous species can result in significant underestimation of alien diversity (Carlton 2009). That only one has been detected to date in South Africa may reflect the fact that most of our

FIGURE 1.—Date of first record for introduced terrestrial molluscs in South Africa, grouped by decade.



alien species are of European origin and that most of the malacologists documenting our fauna in the early years were British or Dutch, and would therefore have been familiar with the species concerned. Edgar Layard, Director of the South African Museum (1855–72) employed the name *Testacella aurigaster* for specimens of a testacellid slug (now known to be the European *T. maugei*) that he found in the museum gardens, but although this name appears in the literature, the species was never formally described.

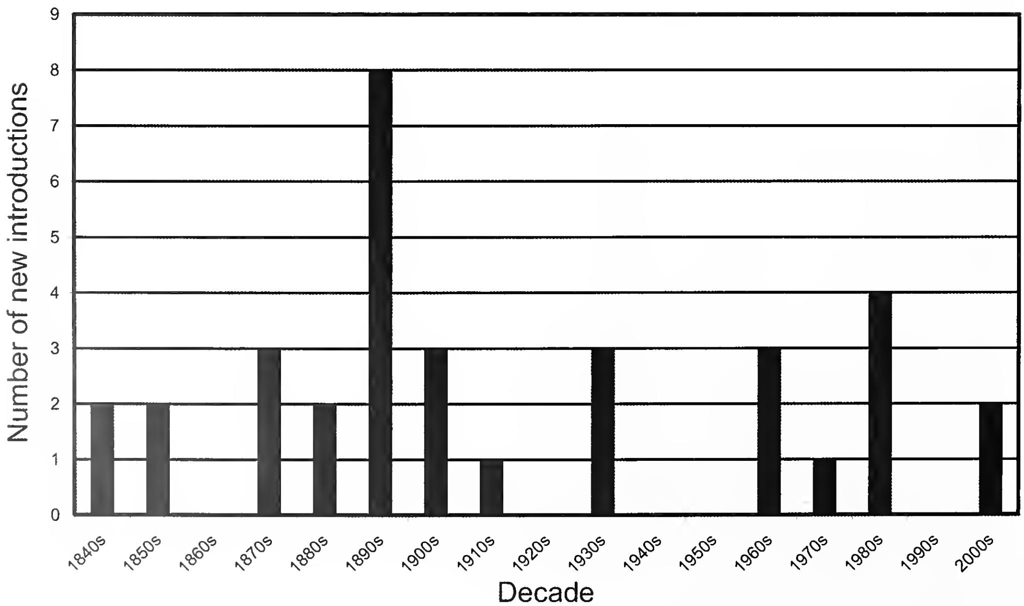
Patterns and processes of introduction

Rate of introduction

Analysis of the rate of introduction requires knowledge of the date of introduction. In most cases this date cannot be precisely determined, since most of the introductions were accidental and only discovered at a later date. In practice, one can only establish a date prior to which the introduction must have take place. This is determined by the earliest collection event. In some cases where the date of collection is not known, the date of death of the collector or their emigration from South Africa can be used to provide a date prior to which collection must have occurred (cf. *Bradybaena similaris* and *Testacella maugei*). If neither the date of collection, nor the collector is known (as is frequently the case), the date of the first published record must be used. These data are presented in Table 1 and Figure 2.

The earliest date recorded for terrestrial molluscs introduced to South Africa, 1846, correlates with that given by Cowie (1998a) for Hawaii (excluding non-native species found in archaeological deposits) and is probably more reflective of the growth in interest in natural history during the mid-19th century than it is of a genuine starting point for terrestrial mollusc introduction in South Africa. As stated above, introductions may well have commenced soon after the first European settlers arrived in the Cape (*circa* 1650). In the ±160 years since the first records of alien snails in the mid-1800s, the rate of introduction has averaged 2.0 species per decade. However, this rate has not been constant, as is evident in Figure 3 which shows a cumulative plot of alien terrestrial mollusc introduction in South Africa (based on date of introduction). In reality, this apparent variation in introduction rate, may be more reflective of variation in the rate of the recording of introductions. It is difficult, if not impossible, to separate rate of introduction from the rate of recording. Figures 1 and 2 are broadly similar and the impact of malacological effort is clearly evident in Figure 2, with a peak corresponding with Melvill & Ponsonby's 1898

FIGURE 2.—Date of introduction of alien terrestrial molluscs in South Africa, grouped by decade (date determined as earliest collection event or record).



publication of the first listing of introduced species, and a hiatus in the 1940s and 1950s following World War II. Outside of these rather abnormal intervals, a rate of 1–3 introductions per decade is probably indicative of a genuine pattern.

Although the cumulative plot in Figure 3 also shows the impact of malacological effort with a steep rise in the 1890s and a plateau in the 1940s and 1950s, it graphically demonstrates that the rate of introduction shows no sign of reaching an asymptote. Given that Robinson (1999) listed 163 species of non-marine molluscs as recognised 'travellers', 131 of which are terrestrial species, and that the current total for South Africa stands at 34, there is a high probability that further introductions will occur (see potential future introductions at the end of this review).

Figure 3 also shows a cumulative plot of species considered to be established in South Africa (excludes both eradicated species and species dubiously established). This demonstrates that a high percentage (28 species, 82%) of introduced species has become established, 13 of which (46%) are invasive, at least on a local scale. In contrast, only 22 out of 59 species (37%) of terrestrial alien molluscs recorded from Hawaii have become established (Cowie 1999). An obvious reason for this difference is not apparent, but it may relate to habitat compatibility and climate matching with colonising countries and major trading partners. The relative percentages of introduced and established alien species in South Africa departs radically from the 'rule of tens' (Williamson 1996), a rule which suggests that only 10% of introduced species become established. A likely explanation for this is that, in the case of snails and slugs, a great many introductions go unnoticed and the species recorded as introductions are by and large those that have in fact already become established. Many of those that are introduced but fail to become established may never actually be detected.

Region of origin

In most cases, the broad region of origin of our introduced species is easily determined and the data are provided in 50-year time slices in Table 2 and summarised graphically in Figure 4. Only one species (*Subulina octona*) is of uncertain origin. Most South African alien terrestrial molluscs, 29 species (84%), originate from Europe, of which nine (26% of the total) are Mediterranean species. This is primarily a reflection of two phenomena, firstly of the European colonial history of South Africa (almost half of these European species were introduced prior to 1900), and secondly of the temperate and Mediterranean, winter rainfall climates prevailing in the Cape. The alien terrestrial mollusc faunas of southern Australia and New Zealand are similarly dominated by European species (Smith 1992; Barker 1999). Other phenomena,

FIGURE 3.—Cumulative plot of numbers of land snails and slugs introduced to South Africa (solid line) and those considered to have become established as alien species (dashed line).

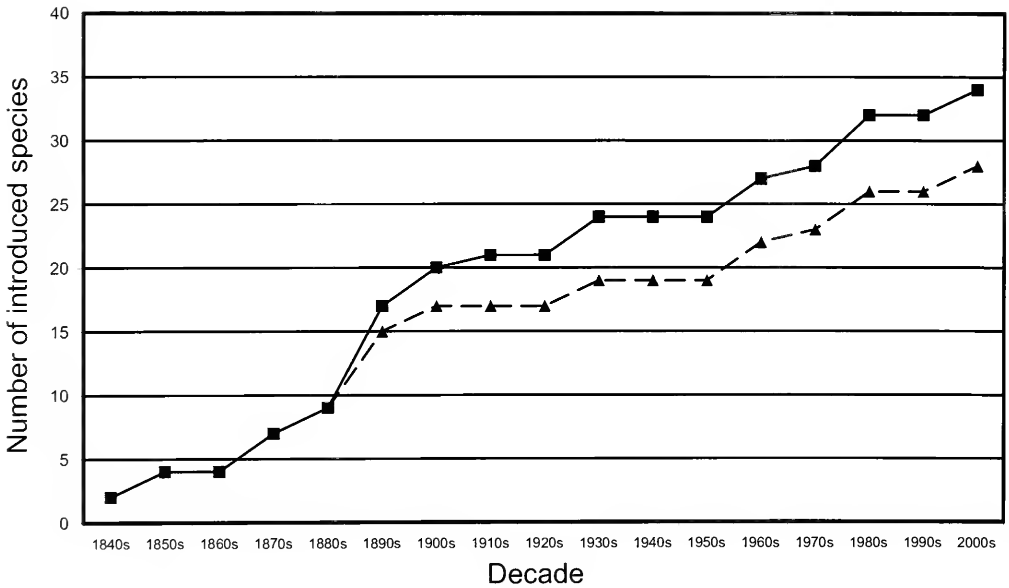


Table 2.—Analysis of alien terrestrial molluscs in South Africa in terms of their region of origin and date of introduction

Region of Origin		**50 year time interval**			**Total**
	pre 1900	1900–49	1950–99	2000–09	
Europe (incl. Holarctic)	11	4	4	1	20
Mediterranean	3	1	5	0	9
North America	1	0	0	1	2
Africa	0	1	0	0	1
Asia	1	0	0	0	1
unknown	0	1	0	0	1
Total	**16**	**7**	**9**	**2**	**34**

such as the adaptability and synanthropic tendencies characteristic of many of these species, has further enabled them to spread and survive in urban areas, even in the summer rainfall region. To date, tropical and subtropical tramp species from other parts of the world occur in conspicuously low numbers and are confined to KwaZulu-Natal (e.g. *Bradybaena similaris*). Although this European-dominated pattern is likely to persist in the Cape, changing patterns of trade, with a growing role for Asian countries, may in the future result in a significant increase in the number of tropical and subtropical species introduced in Durban and along the eastern seaboard. Veronicellid slugs, many of which are important pests, represent a particular concern in this regard (see potential future introductions, below).

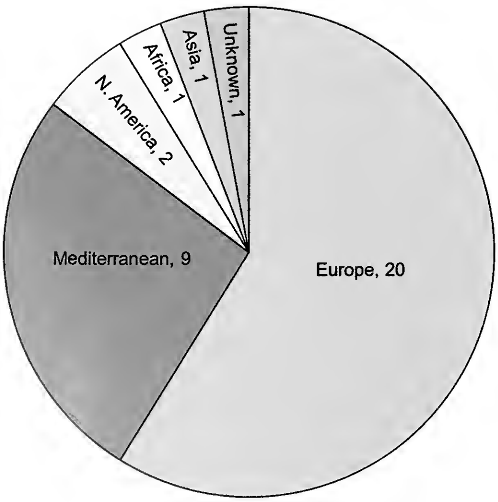


FIGURE 4.—Pie chart illustrating the numbers of species of alien terrestrial molluscs in South Africa in terms of their region of origin.

Site of introduction

An analysis of the site of introduction or at least the first record, reveals that Cape Town has clearly been the primary site for terrestrial mollusc introduction in South Africa (Figure 5). Again this is fully expected given the city's history as the principal arrival destination for early European settlers and its subsequent role as a major port of entry for Europe-derived supplies. The total for Cape Town (20 or 59%) exceeds that of all other localities combined. The temperate, winter rainfall (Mediterranean) climate of the western Cape has doubtless also facilitated the establishment of these European species after introduction. The remaining localities show no obvious pattern of introduction with the exception of Durban. In this case the two species recorded there for the first time, namely *Achatina fulica* (not established) and *Bradybaena similaris*, are the only alien snails of African and Asian origin respectively, yet recorded in South Africa, and both are tropical species. This highlights the fact that Durban, with its subtropical climate, represents a significant risk in terms of the introduction and successful establishment of further tropical tramp species (e.g. veronicellid slugs and subulinid snails), particularly given the expected increase in trade with Asia.

Modes of introduction and dispersal

The routes via which non-indigenous terrestrial molluscs have arrived in South Africa are doubtless many and varied. In the vast majority of cases these introductions will have been accidental. Only *Cornu aspersum*, the European brown garden snail, is known to have been imported deliberately, as a food resource in 1855, but in reality it was prob-

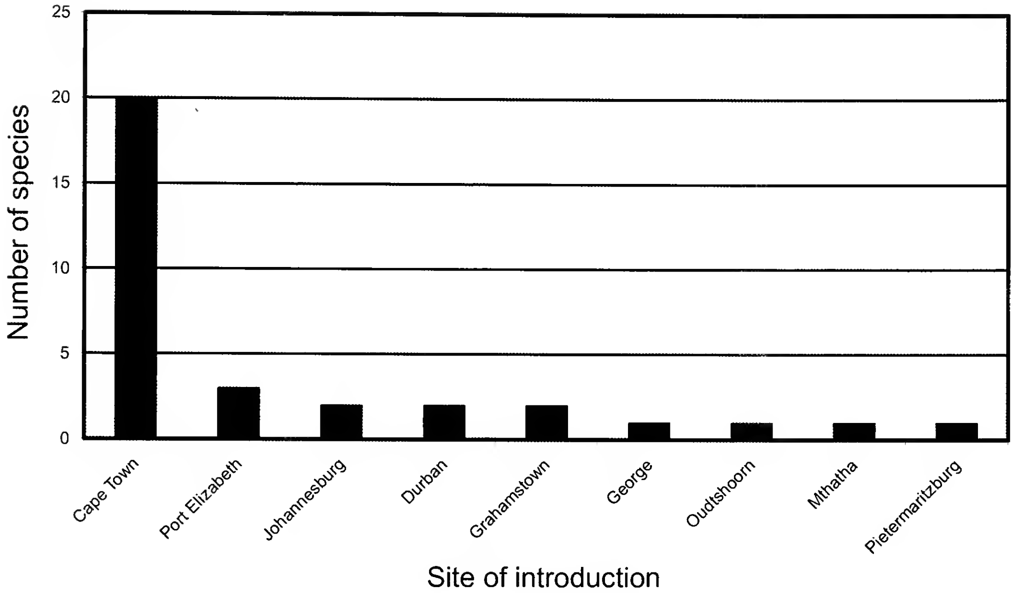


FIGURE 5.—Histogram illustrating the numbers alien terrestrial mollusc species in South Africa of in terms of the site of introduction. (The site of introduction of one species, *Lehmannia nyctelia*, is not known since the first record listed several localities.)

ably an established alien in the western Cape long before this. Fortunately, to date, South Africa has been spared the deliberate and hazardous introduction of non-indigenous terrestrial molluscs for the purposes of biocontrol (but see also *Rumina decollata* below). The streptaxid *Gonaxis gwandaensis* (Preston, 1912) was imported from Kenya by the Department of Agriculture in Stellenbosch during the 1960s, as a potential biocontrol agent for *Theba pisana* (Visser 1973 and W. Sirgel pers. comm.), but the project was evidently aborted without release of the snails.

The routes by which snails and slugs may be introduced to areas beyond their natural range have been reviewed by Cowie & Robinson (2003). Important vectors for accidental introduction include commercial, domestic and military shipments, and agricultural and horticultural products. Indeed it is becoming increasingly evident that the horticultural industry is a major pathway via which alien species, and alien terrestrial molluscs in particular, are both introduced and subsequently dispersed (Dehnen-Schmutz *et al.* 2007; Hayes *et al.* 2007; Cowie *et al.* 2008). The well-watered environments in nurseries and garden centres provide habitats conducive to the proliferation of snail and slug populations, which are then translocated internationally and locally when plants or flowers are exported or purchased. Herbert & Sirgel (2001) noted that the recently introduced *Eobania vermiculata*, although probably not introduced to South Africa via the horticultural trade, had none the less established itself in garden centres in the Port Elizabeth area and that this constituted an important channel through which it was likely to extend its range. A similar process is thought to have contributed to the rapid spread of the slug *Boettgerilla pallens* Simroth, 1912, in Europe (Reise *et al.* 2000). Furthermore, in South Africa where plantation forestry is a major industry, it is likely that within the horticulture sector, the sylviculture industry may represent a particularly important agent in the dispersal of alien species into remote areas where there may be subsequent spread into indigenous habitats. Two newly recorded alien species, *Discus rotundatus* and *Hawaiia minuscula*, have been found in association with forestry enterprises in the remote Langeni area, Eastern Cape. The most likely explanation for this is that the snails are present in sylviculture nurseries and that they were translocated to these remote forestry plantations in the soil around sapling roots. In many areas these plantations are closely juxtaposed to indigenous forests. The same process may also result in native species being translocated to areas beyond their natural range (see *Atoxonoides meridionalis* below).

The extent to which alien terrestrial gastropods have been dispersed by agriculture in

South Africa is also considerable. Although few areas have been sampled in this regard, it is evident that in the interior of Eastern Cape, alien snails and slugs have reached even the most remote farms and the same is probably true in other provinces. These higher altitude regions with cooler temperatures and higher rainfall have a climate not unlike that of temperate Europe from which many of the aliens concerned originate, and they appear to thrive in these areas. Tourism too represents a mechanism by which aliens can be dispersed to remote, pristine habitats via the discarding of waste vegetable matter during food preparation (e.g. *Deroceras* species at isolated bush camps and picnic spots in Hluhluwe Game Reserve, KwaZulu-Natal).

In essence, almost any trade or activity which involves the import or transport of produce, commodities or machinery carries with it the risk of introducing alien gastropods. Produce such as cut flowers, vegetables, fruit and grain represent high risk cargos, but even trades in inanimate objects such as monumental masonry, tiles and flowerpots carry a surprisingly high risk (Robinson 1999; Herbert & Sirgel 2001; Tang 2004). Of all gastropod species intercepted by quarantine officials in the USA between 1993 and 1998, the highest proportion were found in tile shipments (Robinson 1999). Stocks of export ready products from such industries provide ideal resting and aestivation sites for Mediterranean snails. As advocated by Cowie *et al.* (2008), it is important that the industries and stakeholders concerned are made aware of these issues and that quarantine officials are alert to high-risk commodities and high-risk species.

An additional avenue for the introduction of alien species that has emerged in recent years, is by means of electronic mail order via the Internet (Lloyd 2000). The number of species of snail offered for sale, either as potential biological control agents or as pets, is considerable and, unless declared, postal delivery of such items may easily circumvent import regulations and quarantine measures (Smith 2005).

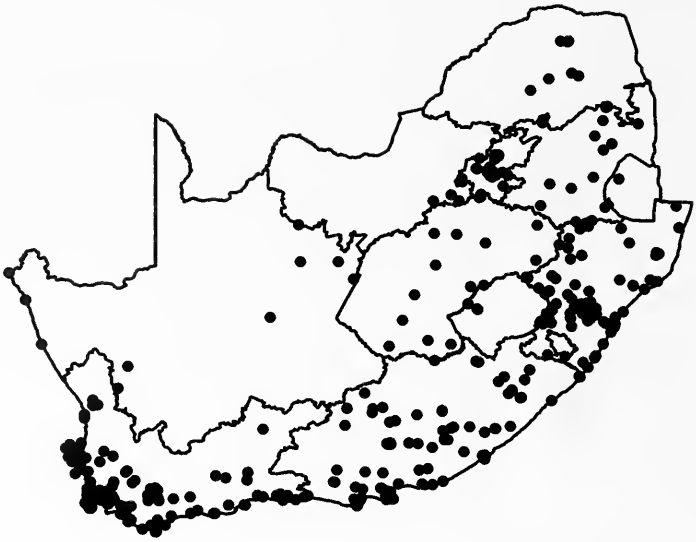


FIGURE 6.—Map of South Africa showing the distribution of all records of alien terrestrial gastropods (many dots represent multiple records).

Current provincial patterns

Any analysis of the current patterns of mollusc distribution in South Africa, for both indigenous and alien species, must acknowledge that sampling effort in the different regions has been far from uniform. Care must therefore be taken not to over interpret the data and draw conclusions that are statistically compromised. Nonetheless, I have undertaken some simple, broad-scale assessments of the South African alien gastropod distributions which reveal patterns that are probably reflective of real trends.

In terms of the collective distribution of aliens in the county as a whole (Figure 6), there are clear concentrations of records in the southwestern Cape, in the Durban–Pietermaritzburg corridor, and in Gauteng. Although these areas include major urban centres and hubs of commercial activity which may facilitate the local introduction and establishment of aliens, it is difficult to disentangle this pattern from that of collecting bias. These are also areas where malacological activity has been greatest. In the western Cape the density of records is undoubtedly increased by the occurrence of Mediterranean species, particularly *Theba pisana* which has spread extensively and in abundance into natural ecosystems. Although collecting effort in the northern and western parts of the country has been very low, the scarcity of records from these regions probably does reflect a genuine pattern correlated with the relatively arid conditions prevailing.

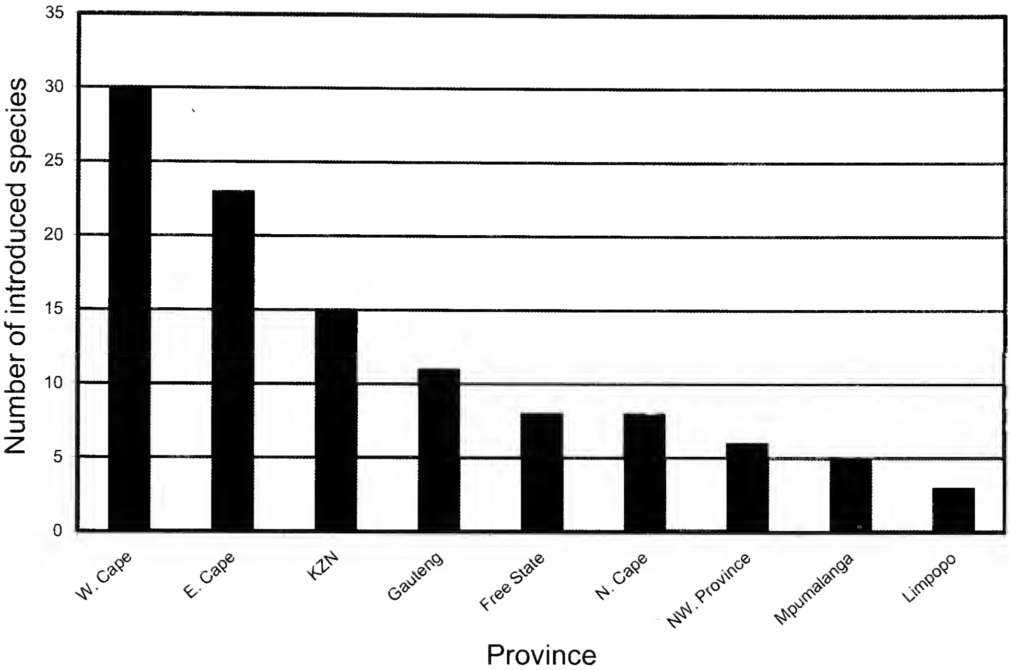


FIGURE 7.—Histogram illustrating species diversity of alien terrestrial molluscs in South Africa in relation to the nine provinces.

Analysis of the distribution of alien species on a provincial basis is depicted in Figure 7 (raw data in appendix). With the exception of the Northern Cape, the coastal provinces clearly have the greatest diversity of alien species. This is no doubt a result of the presence of major ports, favourable climatic conditions and high human population densities. Northern Cape (admittedly poorly sampled) has no significant port and a substantially drier climate (mean annual precipitation < 400 mm, Schulze 1997) than the southern and eastern coastal provinces. In the northern provinces (excluding Gauteng), alien mollusc diversity is generally low, in part due to limited data, but perhaps also because these areas experience highly seasonal rainfall, most of which falls in early to mid-summer (Schulze 1997). Such a rainfall pattern, including a long dry winter, is not likely to favour species of European origin. It is significant that many of the records for Limpopo and Mpumalanga lie along the northeastern Drakensberg Escarpment where rainfall is higher (mean annual precipitation > 1 000 mm, Schulze 1997). The number of alien species recorded from Gauteng is more than double that of the other three northern provinces. This is entirely expected given the high trade volumes associated with the major commercial hubs and conurbations in the province, and the extent of habitat transformation found in suburban gardens and irrigation-intensive agriculture.

Only one alien species, *Cornu aspersum*, is recorded in all nine provinces (Figure 8). Although sometimes found in somewhat disturbed natural habitats near the coast, this species is generally confined to transformed habitats. It is, however, an extraordinarily successful synanthrope and occurs almost wherever there are human settlements, even in the most remote areas. *Cochlicopa lubrica*, *Limacus flavus* and *Zonitoides arboreus* occur in six provinces and are species commonly associated with domestic habitats and greenhouse horticulture. Species in the genera *Arion*, *Deroceras*, *Lehmannia*, *Oxychilus* and *Vallonia*, all recognised travelling genera, are generally recorded from three or more provinces. Of the eleven species recorded from a single province, eight occur only in Western Cape. Mostly these were relatively early introductions and the species concerned, although established, have not spread far beyond the greater Cape Town area. Of the three remaining species recorded from only one province, two are tropical species recorded only from KwaZulu-Natal and the other a newly discovered introduction, *Hawaiia minuscula*, which is almost certainly more widely distributed than the single record suggests.

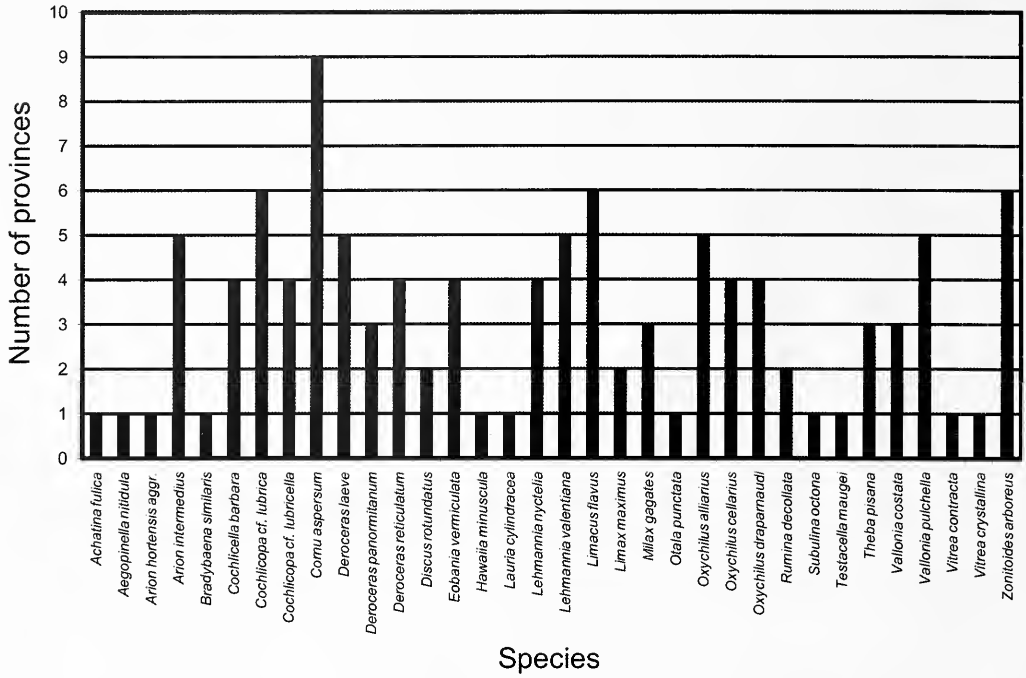


FIGURE 8.—Histogram illustrating the number of South African provinces in which individual alien species have been recorded.

Human mediated range expansion of indigenous species

The species treated in this review are all clearly exotic, their native ranges being far removed from southern Africa, and their introduction to this part of the world is clearly a result of human activities. The role of humans as dispersal agents, however, is not restricted to species from distant lands. Below I give a number of examples where evidence strongly suggests that species indigenous to southern Africa have extended their ranges through human agency. Interestingly, most are slugs.

Laevicaulis alte (Férussac, 1821) [Veronicellidae], native to Central and East Africa south to KwaZulu-Natal, this slug has been recorded in climatically improbable localities in the western parts of southern Africa (Vredendal and Windhoek, W. Sirgel pers. comm.), to which it has almost certainly been introduced via translocated plants.

Cochlitoma zebra (Bruguière, 1792) [Achatinidae], a species of the southern and eastern Cape, has an isolated population in Hout Bay on the Atlantic Cape coast that is believed to have arisen through local translocation (Sirgel 1989). In this case the translocation may have been deliberate, for reasons of aesthetic appeal or human curiosity.

Urocyclus kirkii Gray, 1864 [Urocyclidae], a species ranging from Tanzania to the highlands on the Zimbabwe–Mozambique border, has a disjunct population occurring in gardens, parks and remnant patches of indigenous habitats in suburban areas in the Durban Metro and along the KwaZulu-Natal south coast (Herbert & Kilburn 2004). It seems probable that this population derives from individuals translocated from further north.

Elisolimax flavescens (Keferstein, 1866) [Urocyclidae] is a species occurring primarily in southeastern Africa, from Zimbabwe and southern Mozambique, south to the border between KwaZulu-Natal and Eastern Cape, but an isolated population has been found in gardens in East London (Herbert & Kilburn 2004). This is an area where the species is not found in indigenous habitats (M. Cole pers. comm.), strongly suggesting that its occurrence there is not natural.

Atoxonoides meridionalis (Forcart, 1967) [Urocyclidae] ranges naturally from the eastern highlands of Zimbabwe southwards to the Eshowe–Mtunzini area in northern

KwaZulu-Natal, but several specimens have recently (2005) been found in Pietermaritzburg, in disturbed mist-belt grassland habitat close to exotic plantations. It is probable that this results from translocation mediated by the sylviculture industry.

Identification

The task of establishing whether or not a species is introduced and determining its identity is often not an easy one. For the larger more well-known species it may be relatively simple, but the list of travelling species and those intercepted at ports of entry (Robinson 1999) includes a number of speciose families and genera often containing many closely similar species, for which species identification requires considerable experience and expertise (e.g. *inter alia* Agriolimacidae, Arionidae, Hygromiidae, Limacidae, Oxychilidae, Subulinidae, Succineidae, Vertiginidae, Veronicellidae). In these cases identification may be frustratingly difficult, particularly when the country of origin is not known, which of course is usually the case, unless the material was intercepted at a port of entry on a shipment of known origin. Since the expertise necessary to permit identification is often not available locally, it is important that channels of communication be established with sources of such expertise overseas (e.g. USDA Animal and Plant Health Inspection Service—Plant Protection and Quarantine; South Australia Research and Development Institute).

In this regard it is pertinent to note that a number of unidentified terrestrial gastropod taxa have been collected in disturbed or transformed habitats in South Africa (material in the Natal Museum). These taxa belong to the families Succineidae, Subulinidae and Vertiginidae and appear not to be referable to any of the indigenous species described to date nor to any of the currently known alien species. It seems likely that when studied in more detail these will prove to be of allochthonous origin, rather than being undescribed species. An additional caveat that needs to be considered in connection with the identification of alien species, particularly those belonging to genera with many closely similar species, is the tendency to assume that newly collected samples must belong to one of the species already recorded as an alien in South Africa. This of course is not justified, and highlights the importance of on-going vigilance and careful scrutiny of all samples belonging to such genera with reference to the relevant taxonomic literature on a broad scale.

Eradication and control

For species which present little or no pest risk and are unlikely to represent a threat to the indigenous biota, eradication attempts are probably not warranted. However, for species known to be significant pests in other parts of the world, and for which environmental conditions in South Africa are likely to be favourable, eradication is an attractive option. Nonetheless, this is notoriously difficult to achieve. Once established, alien species are almost impossible to eliminate (Myers *et al.* 2000). Examples of the successful eradication of pestiferous exotic terrestrial molluscs are few. *Achatina fulica* was successfully eradicated in Florida (Simberloff 1996) and Micronesia (Cowie 2001b), but such campaigns are often costly. The eradication of *A. fulica* in Florida in the late 1960s took more than seven years and cost approximately US$ 700 000 (Poucher 1975), but a subsequent estimate of costs, had the eradication not been effected, cited a figure of US$11 million per annum in 2002 (Smith 2005).

In South Africa, an insightful and comprehensive eradication effort resulted in the elimination of the potentially pestiferous helicid *Otala punctata* in Cape Town during the late 1980s (Herbert & Sirgel 2001). A similar but undocumented campaign also eliminated a small population of *Rumina decollata* in Cape Town in the early 1990s (W. Sirgel pers. comm.). In contrast, a half-hearted response to the discovery of *Eobania vermiculata* in Port Elizabeth during 1987, failed to eliminate the species. It is now an established pest in the area and its range is spreading. The message here is clear—the early detection of new introductions is critical and the ensuing eradication campaign must be vigorous and multi-pronged, involving visual removal by hand, application of molluscicides, elimination of food resources and refuges, and public awareness campaigns (Poucher 1975; Herbert & Sirgel 2001). Although this may come at a high initial cost, the alternative is a continuous battle to keep populations at bay so as to limit the downstream economic impact—ongoing costs which are ultimately likely to far exceed the cost of early eradication. A broad discussion of eradication of exotic species was provided by Myers *et al.* (2000). At all times, the risk to non-target native species must be considered, particularly in the case of biocontrol (see *Achatina fulica* below).

The issues of snail and slug control, and best pest management practices are beyond the scope of the present review. Useful information can be found in many sources including Godan (1983, 1999), Baker (1986), Henderson (1989, 1996), South (1992), Preston *et al.* (2000), Barker (2002a) and Bailey (2007). Additional data resources are plentiful on the Internet. However, for some of the more pestiferous species, I have included information on their behaviour and reproductive cycle, and references to further sources of information, since such data may be important in the strategic use of molluscicides, both in terms of where and when to apply them for maximum effect, i.e. around over-wintering or aestivation aggregation sites, just before the reproductive season, and again soon after the hatching period.

Biological traits characteristic of successful colonising gastropods*	
generalist food requirements	wide native distribution (broad climatic tolerance)
catholic habitats requirements	efficient dispersal
tendency to be synanthropic	tolerance of disturbance
r-selected life-history traits	semelparous life-history
rapid reproduction	ability to reproduce by self-fertilisation or parthenogenesis
high fecundity	small egg/juvenile size
adaptive life-history traits (ability to change strategy e.g. from annual to biennial)	annual reproductive season
ability to survive translocation in a dormant state (aestivation)	climate matched with native range

*Data largely from Cowie (1998a) and Cowie *et al.* (2009).

Cornu aspersum (Müller, 1774), typical specimen, Stanford, W. Cape [2007].

Checklist and classification of introduced terrestrial molluscs in South africa

Order: Eupulmonata

Suborder: Stylommatophora

Superfamily: Cochlicopoidea

Family: Cochlicopidae

Cochlicopa cf. *lubrica* (Müller, 1774)
Cochlicopa cf. *lubricella* (Rossmässler, 1834)

Superfamily: Pupilloidea

Family: Lauriidae

Lauria cylindracea (Da Costa, 1778)

Family: Valloniidae

Vallonia costata (Müller, 1774)
Vallonia pulchella (Müller, 1774)

Family: Vertiginidae

Vertigo ?antivertigo (Draparnaud, 1801)†

Superfamily: Achatinoidea

Family: Achatinidae

Achatina fulica Bowdich, 1822

Family: Ferussaciidae

Cecilioides acicula (Müller, 1774)†

Family: Subulinidae

Subulina octona (Bruguière, 1789)
Rumina decollata (Linnaeus, 1758)

Superfamily: Testacelloidea

Family: Testacellidae

Testacella maugei Férussac, 1819

Superfamily: Punctoidea

Family: Discidae

Discus rotundatus (Müller, 1774)*

Superfamily: Gastrodontoidea

Family: Gastrodontidae

Zonitoides arboreus (Say, 1816)

Family: Oxychilidae

Aegopinella nitidula (Draparnaud, 1805)*
Oxychilus alliarius (Miller, 1822)
Oxychilus cellarius (Müller, 1774)
Oxychilus draparnaudi (Beck, 1837)

Family: Pristilomatidae

Hawaiia minuscula (Binney, 1841)*
Vitrea contracta (Westerlund, 1871)*
Vitrea crystallina (Müller, 1774)

Superfamily: Parmacelloidea

Family: Milacidae

Milax gagates (Draparnaud, 1801)

Superfamily: Limacoidea

Family: Agriolimacidae

Deroceras laeve (Müller, 1774)
Deroceras panormitanum (Lessona & Pollonera, 1882)
Deroceras reticulatum (Müller, 1774)

Family: Limacidae

Lehmannia nyctelia (Bourguignat, 1861)
Lehmannia valentiana (Férussac, 1822)
Limacus flavus (Linnaeus, 1758)
Limax maximus Linnaeus, 1758

Superfamily: Arionoidea

Family: Arionidae

Arion hortensis Férussac, 1819 (aggregate)
Arion intermedius Normand, 1852

Superfamily: Helicoidea

Family: Bradybaenidae

Bradybaena similaris (Férussac, 1822)

Family: Cochlicellidae

Cochlicella barbara (Linnaeus, 1758)

Family: Helicidae

Cornu aspersum (Müller, 1774)
Eobania vermiculata (Müller, 1774)
Otala punctata (Müller, 1774)
Theba pisana (Müller, 1774)

Based on Bouchet *et al.* 2005.

* new record

† doubtful record

Bradybaena similaris (Férussac, 1822), crawling animal, Bridgevale, Durban North, Parks Dept nursery (NMSA V9234 [2001]).

Species treatments SNAILS

Family: Cochlicopidae Pilsbry, 1900

Small, elongate snails, generally highly glossy and somewhat translucent. Herbivorous, feeding primarily on dead vegetation and therefore perhaps rather more beneficial than harmful, assisting in the breakdown of plant material and thus contributing to the recycling of soil nutrients. Native to Europe, Asia and North America. Known in American and Australian literature under the name Cionellidae (Pilsbry 1948; Smith 1992, 1998a), but *Cionella* Jeffreys, 1830, is a junior synonym of *Cochlicopa* Férussac, 1821 (for further discussion see Gittenberger 1983, Barker 1999; Bouchet & Rocroi 2005).

Two *Cochlicopa* species have been recorded in South Africa, *C. lubrica* and *C. lubricella*. Although neither has been recorded from more than a few localities, both may in reality have spread much further than the available records suggest. Their small size and cryptic habit undoubtedly leads to them being overlooked. The generally dry climate in much of South Africa, however, may not be favourable to them and their capacity to spread beyond synanthropic habitats may be limited.

Distinguishing between *Cochlicopa* species is not easy, even for experts on the European fauna, and there has been some debate regarding the number of validly distinct species (Quick 1954; Outeiro *et al.* 1990; Falkner 1992; Gittenberger & Bakker 1992; Armbruster 1995, 1997; Barker 1999; Anderson 2005). Although this uncertainty has not been completely resolved, most workers seem to be of the opinion that *C. lubrica* and *C. lubricella* are genuinely distinct. However, Giusti & Manganelli (1992) provided evidence to suggest that, whereas the species may be separable in one region (Scandinavia), they may not be in another (Italy). This they believed depends upon the relative proportions of self- and cross-fertilisation within populations, cross-fertilisation favouring greater variability and intergradation in shell characters, and self-fertilisation limiting morphological variability and perpetuating lineage distinctness. To resolve this they proposed that the oldest name be used at the level of supraspecies i.e. *Cochlicopa* suprasp. *lubrica*, followed by the specific name of the material if this can be determined. As an alien in southern Africa, one might expect that self-fertilization and founder effects would be important in nascent *Cochlicopa* populations, and thus that the lineages would retain their morphological identities. This indeed appears to be the case, and therefore I treat the two as separate entities. However, since recent molecular studies suggest that in Europe these morphological characters are not indicative of discrete monophyletic lineages (Armbruster & Bernhard 2000), I follow Anderson (2005) in referring to them as *Cochlicopa* cf. *lubrica* and *C.* cf. *lubricella*.

The reproductive biology of *Cochlicopa* species is not well documented. In *C.* cf. *lubrica*, maturity is reached in 21–24 months, the adults living for a further year. Egg-laying commences shortly after the outer lip of the shell has thickened, the eggs being deposited singly, often covered in faecal strands (Barker 1999).

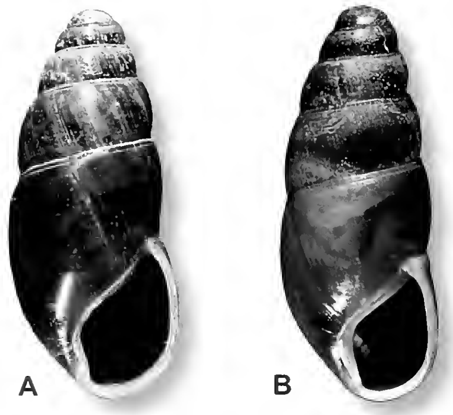


FIGURE 9.—*Cochlicopa* species. A, *Cochlicopa* cf. *lubrica*, Hogsback, E. Cape, length 5.8 mm (NMSA V6375 [1997]); B, *Cochlicopa* cf. *lubricella*, Bryanston, Johannesburg, length 5.2 mm (NMSA B7295 [1977]).

Cochlicopa cf. *lubrica* (Müller, 1774)

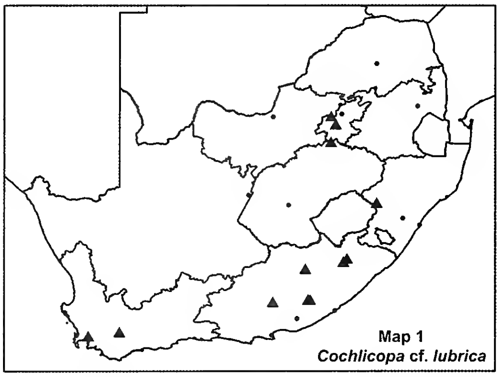
(slippery moss snail, glossy pillar)

Figure 9A

Helix lubrica Müller 1774: 104.

Cochlicopa lubrica; Van Bruggen 1980: 225, fig. 2.

Type loc.: Not cited by Müller, but presumed to be Frederiksdal, NE of Copenhagen, Denmark.



Map 1
Cochlicopa cf. *lubrica*

Description: Shell small and rather elongate, spire bluntly rounded; 5–6 whorls; highly glossy, essentially smooth save for microscopic growth-lines; outer lip slightly thickened at maturity; umbilicus lacking. Translucent, pale to dark brown, frequently honey-coloured, outer lip paler. Length ± 4.8–7.7 mm.

Habitat: In Europe, *C.* cf. *lubrica* is reported to occur almost anywhere where conditions are moderately damp, including areas with non-calcareous soils (Kerney 1999); largely synanthropic in North America (Forsyth 2004). Known in South Africa mostly from suburban gardens and transformed environments associated with human habitation; beneath plant cover, under objects lying on the ground, and on walls. Evidently may occur in large numbers. Has also been found in indigenous habitats in the Somerset East area.

Date of introduction: Prior to 1978.

First SA record: Van Bruggen (1980), suburban garden in N.W. Johannesburg, Gauteng.

Global distribution: Native distribution Holarctic. Introduced also to Venezuela (Van Bruggen 1980), St Helena (Crowley & Pain 1977) Réunion (Stévanovitch 1994; Griffiths & Florens 2006), Sri Lanka (Naggs *et al.* 2003), Australia (Smith 1992) and New Zealand (Barker 1999).

Distribution in SA (Map 1): Recorded from W. Cape (Stellenbosch [W. Sirgel pers. comm.] and the foothills of the eastern Langeberge), E. Cape (Dordrecht, Hogsback, Maclear, Somerset East, Ugie), Free State (Sasolburg), KwaZulu-Natal (Champagne Castle resort), Gauteng (Johannesburg [Northcliff]) and N.W. Province (Pelindaba).

Pest status: Insignificant, perhaps even beneficial in decomposition and nutrient recycling, although there is some evidence that green as well as brown plant material may be consumed (Barker 1999). Known to serve as an intermediate host for dicrocoeliid trematode parasites of sheep and goats (Otranto & Traversa 2002).

Similar indigenous species: None.

Notes: Self-fertilization is frequent (Barker 1999).

Cochlicopa cf. *lubricella* (Rossmässler, 1834)

(slender moss snail)

Figure 9B

Achatina lubricella Rossmässler 1834: 6 [in synonymy of *Achatina lubrica*].

Bulimus ?lubricus var. *lubricella* Porro 1838: 53, 54, pl. 2, fig. 8b.

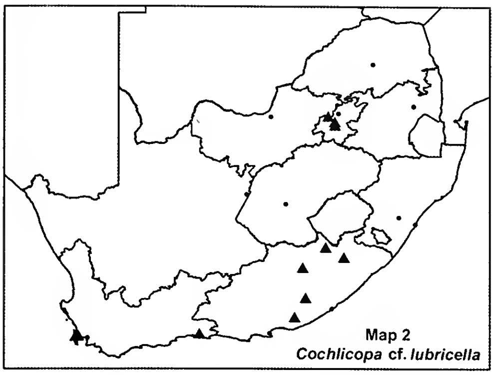
Cochlicopa lubricella; Van Bruggen 1967: 501; 1981: 71; 1998: 85.

Type loc.: Jedlersee, near Vienna, Austria.

Description: Very similar to *C.* cf. *lubrica* (above), but differs in having a slightly smaller and narrower shell. Length and width ranges given by different authors vary somewhat (Table 3), but this is perhaps not unexpected in widely distributed species of catholic habits. Of these two dimensions, shell width appears to be the more reliable metric for species discrimination (Waldén 1955; Gittenberger 1983; Armbruster 1995). The width of South African specimens identified by Van Bruggen (1980) falls within these ranges (viz: 2.4–2.6 mm for *C.* cf. *lubrica* and 1.9–2.1 mm

Table 3.—Shell dimensions recorded for *Cochlicopa* cf. *lubrica* and *C.* cf. *lubricella* by European authors

Author	C. cf. lubrica		C. cf. lubricella	
	length [mm]	width [mm]	length [mm]	width [mm]
Waldén, 1955	4.75–7.05	2.10–2.80	4.20–5.10	1.80–2.20
Gittenberger, 1983	–	2.50–2.90	–	2.00–2.50
Kerney & Cameron, 1979	5.0–7.5	2.40–2.90	4.50–6.80	2.10–2.50
Armbruster, 1995	4.85–7.64	2.19–3.13	3.75–5.70	1.75–2.29



for *C.* cf. *lubricella*). Armbruster (1995) found only a small percentage of animals occurring in an overlap zone of 2.19–2.29 mm for shell width. In contrast, length ranges overlapped to a greater extent in the zone 4.85–5.70 mm. In addition, Quick (1954) observed that the coloration of the head-foot and viscera was somewhat darker in *C. lubrica* (smoky brown) than in *C. lubricella* (yellow-brown). This difference is slight and difficult to assess if only one species is present, but it does seem to be the case in samples from South African localities where the two species co-occur.

Habitat: In its native range *C.* cf. *lubricella* lives in a range of habitats, frequently together with *C.* cf. *lubrica*, but generally favours somewhat drier places than that species (Killeen 1992; Kerney 1999). Known in South Africa primarily from gardens; beneath plant cover, under objects lying on the ground, and on walls. Has also been recorded in indigenous forest in the Knysna area.

Date of introduction: Prior to 1965.

First SA record: Van Bruggen (1967), grounds of Rhodes University, Grahamstown, E. Cape.

Global distribution: Native distribution Holarctic. Evidently not widely introduced to other regions.

Distribution in SA (Map 2): Recorded from W. Cape (Cape Town [Constantia, Kenwyn and Kirstenbosch], Knysna), E. Cape (Barkly East, Dordrecht, Grahamstown, Hogsback, Maclear), Gauteng (Johannesburg [Bryanston and Westcliffe] and N.W. Province (Pelindaba). Also known from Zimbabwe (Harare) (Van Bruggen 1981).

Pest status: Insignificant, perhaps even beneficial in decomposition and nutrient recycling.

Similar indigenous species: None.

Notes: The name *Cochlicopa lubricella* has traditionally been attributed to Porro (1838) [with the type locality of Como in northern Italy]. Details concerning the first valid use of the name have been provided by Quick (1954) and Falkner *et al.* (2002), but the matter is subject to interpretation. I follow Falkner *et al.* (2002) and most recent authors in attributing the name to Rossmässler (1834) [with the type locality of Jedlersee, near Vienna, Austria].

Family: Lauriidae Steenberg, 1925

Small to minute snails, often with rather elongate, pupiform shells and frequently with teeth or denticles in the aperture. Europe, Caucasia and Africa.

The higher taxonomy of superfamily Pupilloidea, to which the Lauriidae belongs, is poorly understood and there seems little agreement as to the composition and ranking of the various suprageneric taxa within the superfamily. The only confirmed alien pupillid in southern Africa belongs to the genus *Lauria* Gray, 1840, a genus with several indigenous species and an unusual, disjunct southern African–European distribution (Van Bruggen 1991). A record of *Pupoides coenopictus* (Hutton, 1834) from Jansenville, E. Cape was rejected by Connolly (1939) [see excluded species below]. *Lauria* belongs to the Lauriidae, a taxon which has traditionally been ranked as a subfamily, but which recent European checklists and classifications treat as a family in its own right (Bank *et al.* 2001; Falkner *et al.* 2001; Anderson 2005; Bouchet & Rocroi 2005). The genus is not well known biologically, but *L. cylindracea* is ovoviviparous and thought to be relatively long-lived for a minute snail (4–5 years) (Heller *et al.* 1997).

Lauria cylindracea (Da Costa, 1778)

(common chrysalis snail)

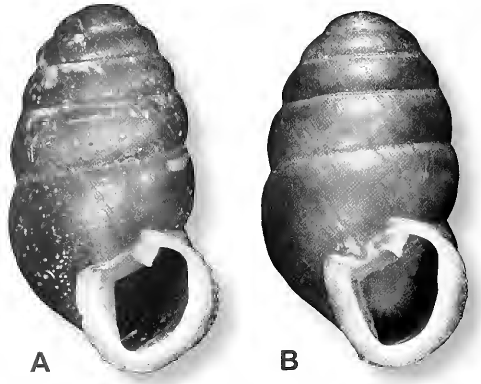
Figure 10

Turbo cylindraceus Da Costa 1778: 89, pl. 5, fig. 16.

Pupa tabularis Melvill & Ponsonby 1893: 20, pl. 3, fig. 3.

Pupa umbilicata Draparnaud 1801; Gibbons 1879: 282; Melvill & Ponsonby 1898: 184.

Jamina tabularis; Connolly 1912: 184.



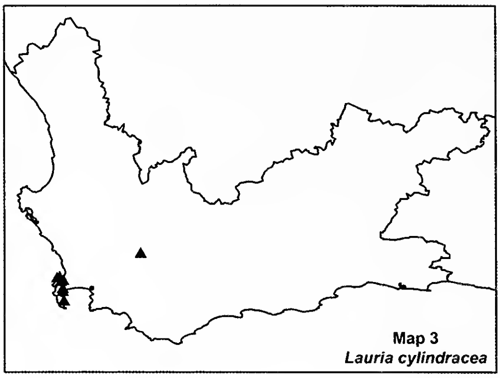


FIGURE 10.—*Lauria cylindracea* (Da Costa, 1778), Cape Town. A, length 3.6 mm; B, length 3.2 mm (NMSA A9429 [undated, *ex* Ponsonby, thus pre 1916]).

Lauria tabularis; Connolly 1939: 400.

Lauria cylindracea; Quick 1952: 183; Verdcourt 1963: 406; Van Bruggen 1973; 1991.

Type loc.: England, several localities cited in original description.

Description: Shell very small, elongate-ovate to subcylindrical with 6–7 convex whorls; smooth except for microscopic growth-lines; aperture lip strongly thickened and flaring outward when mature; upper part of inner lip (parietal region) with a low angular tooth or ridge, often fused with top of outer lip; umbilicus present but narrow. Pale brown to deep honey-brown, aperture lip whitish. Length 3.0–4.5 mm.

Habitat: In its native range *L. cylindracea* lives in a wide variety of habitats including woods, grassland, gardens, hedges, cropland and waste ground. Generally favours relatively dry habitats such as stone walls (Kerney 1999) and usually avoids very wet places, except in Israel (Heller *et al.* 1997). Known in South Africa from gardens, vineyards and exotic conifer plantations.

Date of introduction: Prior to 1879.

First SA record: Gibbons (1879, as *Pupa umbilicata*), Cape Town, W. Cape (see notes below), first recoded under the name *Lauria cylindracea* by Quick (1952).

Global distribution: Native to western Europe and the Mediterranean. Introduced also to North America (Barker 1999; Robinson 1999; Forsyth 2004), Caribbean (Rosenberg & Muratov 2006), St Helena (Crowley & Pain 1977; Ashmole & Ashmole 2000), Tristan da Cunha (Preece 2001), Réunion (Stévanovitch 1994; Griffiths & Florens 2006 ?=*Lauria bourbonensis* Pilsbry, 1922) and New Zealand (Barker 1999).

Distribution in SA (Map 3): Recorded only from the SW Cape (Cape Town and Cape Peninsula, and the Worcester area). Verdcourt (1963) listed the species amongst material from 'Aleudia, Transvaal', but this was incorrectly localised (Van Bruggen 1973).

Pest status: Probably insignificant on account of its small size and fungal diet (Heller *et al.* 1997).

Similar indigenous species: All *Lauria* species are similar and there are four indigenous species occurring in South Africa (Connolly 1939). *L. cylindracea* differs from these in having a more strongly developed aperture lip, a narrower umbilicus and a rather less prominent tooth on the parietal lip, that is short and does not extend far into the aperture. In addition, in *L. cylindracea* the basal angle running posteriorly from just behind the aperture lip is stronger and developed into a rounded, ridge-like rib. *L. dadion* (Benson, 1864), which also occurs in the Cape Town area, lives predominantly in indigenous forest and woodland.

Notes: Gibbons (1879) recorded this species from Cape Town as *Pupa umbilicata* Draparnaud, 1801, a name now considered to be a junior synonym of *L. cylindracea*. This record was subsequently dismissed by Connolly (1939) who considered that Gibbon's material represented an indigenous species that had been described by Melvill & Ponsonby (1893), also on the basis of Cape Town material, as

Pupa tabularis. Van Bruggen (1991) has subsequently shown that, as Connolly also suspected, *L. tabularis* and *L. cylindracea* in reality represent the same species and we must therefore assume that the South African population is an introduced one. The fact that the only records come from suburban areas, pine plantations and vineyards strongly supports this. Further information on the biology of this species was provided by Heller *et al*. (1997).

Family: Valloniidae Morse, 1864

A family of very small, low-spired to globular snails, primarily from the temperate regions of the northern hemisphere. One genus, *Vallonia*, has been introduced to South Africa. These are ground-dwelling snails, rarely climbing more than a few centimetres above soil level, and typically inhabit open, not densely vegetated habitats, e.g. grasslands, damp meadows and drier rocky areas, often with little shade. Their diet comprises mostly decaying vegetable matter, but some will also occasionally eat living green plant material. They are not generally considered problematic, although *Vallonia excentrica* Sterki, 1893, can evidently be a pest of seeds and seedlings of meadow plants in New Zealand (Barker 1985, 1999), where it occurs in abundance in improved pastures in the north of the North Island (Barker 2002b).

Vallonia species are thought to be predominantly self-fertilising, no doubt one of the factors contributing to some of the taxonomic problems outlined below (cf. also *Cochlicopa* species). Further biological data can be found in Gerber (1996).

Vallonia costata (Müller, 1774)

(ribbed grass snail)

Figure 11

Helix costata Müller 1774: 31.

Vallonia costata; Gerber 1996: 156; Van Bruggen 1998: 85.

Vallonia enniensis (*non* Gredler, 1856); Cortie 1998: 8.

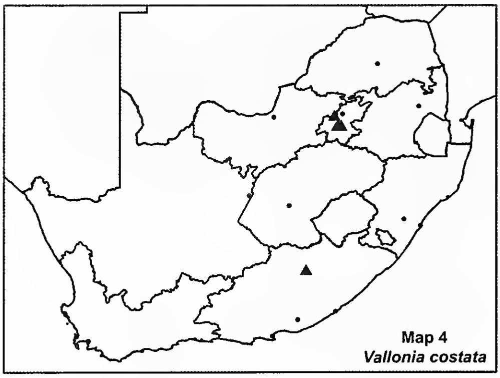
Type loc.: Frederiksdal, near Copenhagen, Denmark.

Description: Shell very small with a low, almost flat spire, overall shape disc-like;

FIGURE 11.—*Vallonia costata* (Müller, 1774), Romance Farm, near Dordrecht, E. Cape, diameter 2.5 mm (NMSA W6751 [2009]).

whorls 3–4, slightly flattened below suture; sculptured by relatively widely spaced axial ribs with finer, close-set intermediaries; ribs derived primarily from periostracum and often lost in old and dead shells; aperture rounded and with a flaring and internally thickened lip in adults; umbilicus broad. Translucent, dirty greyish white, thickened lip of aperture opaque white; periostracum pale corneous brown, often with soil particles attached. Diameter 2.2–2.7 mm.

Habitat: In its native Europe *Vallonia costata* lives in relatively dry, open habitats, often in chalky areas, under logs, amongst stones and on walls, in hedgebanks, short grassland and sand dunes, less often in wooded habitats and marshy places (Killeen 1992; Gerber 1996; Kerney 1999); often gregarious. Little South African material is available, but this has generally been found in gardens (suburban and rural), usually under objects lying on the ground.



Date of introduction: Prior to 1980 (J. Hemmen pers. comm. via J. Gerber).

First SA record: Gerber (1996), Bedfordview, Johannesburg, Gauteng.

Global distribution: Native to and widely distributed in the Palaearctic, and to a lesser extent in the Nearctic (Gerber 1996). Not widely introduced to other areas. Although recorded from Australia (Cotton 1954), this was subsequently rejected by Smith & Kershaw (1979), but mentioned again by Smith (1992). Its occurrence there requires confirmation (Stanisic 1998b). Recorded also from Israel (Roll *et al.* 2009) and Japan (Sasaki 2008).

Distribution in SA (Map 4): To date recorded only from E. Cape (Dordrecht area), Gauteng (Johannesburg) and North West Province (Pelindaba).

Pest status: Probably insignificant due to its small size and its diet comprising primarily decaying vegetable matter.

Similar indigenous species: None; the small flattened, axially ribbed shell, with its thickened and flaring aperture lip is characteristic (but see *V. pulchella* below).

Notes: Cortie (1998) tentatively identified *Vallonia* material from a Gauteng garden as *V. enniensis* (Gredler, 1856), but the specimens concerned appear to have fewer, more widely spaced ribs than that species and were almost certainly examples of *V. costata*.

Vallonia pulchella (Müller, 1774)

(smooth grass snail, lovely vallonia)

Figure 12

Helix pulchella Müller 1774: 30; Benson 1850: 217; Gibbons 1879: 282.

Vallonia pulchella; Melvill & Ponsonby 1898: 184; Connolly 1939: 373; Quick 1952: 188; Van Bruggen 1964: 162; 1980: 227; 1998: 86; Gerber 1996: 48; Herbert & Kilburn 2004: 271.

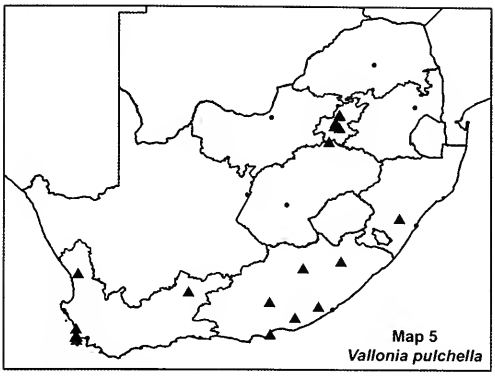
Vallonia excentrica; Connolly 1912: 159; 1916: 186.

Type loc.: Frederiksdal, near Copenhagen, Denmark.

Description: Very similar to *Vallonia costata* (above), but lacking axial ribs; aperture with a more abruptly flaring lip, but not as strongly thickened internally; shell smooth save for indistinct growth-lines. Translucent, whitish to pale buff, sometimes rather dirty; thickened lip of aperture opaque white. Diameter 2.0–2.5 mm.

Habitat: Like *Vallonia costata* this species also favours open habitats, but is generally found in somewhat moister environments, such as marshes, damp pastures, dune slacks and river flood plains (Killeen 1992; Gerber 1996; Kerney 1999); frequently in habitats transformed by humans. Little habitat information is associated with South African specimens, but most originated in suburban gardens.

FIGURE 12.—*Vallonia pulchella* (Müller, 1774), Pietermaritzburg, diameter 2.3 mm (NMSA A9968 [1927]).



Date of introduction: Prior to 1846.

First SA record: Benson (1850), 'High Constantia', Cape Town, W. Cape.

Global distribution: Native to, and widely distributed in the Palaearctic and eastern North America. Introduced also to the western USA (Pilsbry 1948), Canada (Forsyth 2004), Central and South America (Gerber 1996; Scarabino 2003; Simone 2006), Bermuda (Bieler & Slapcinsky 2000), Ascension (Ashmole & Ashmole 1997), Malta (Giusti *et al.* 1995), Israel (Roll *et al.* 2009), Madagascar (Gerber 1996) the Mascarene Islands (Stévanovitch 1994; Griffiths & Florens 2006), India (Mitra *et al.* 2005), China (Gerber 1996), mainland Australia and Tasmania (Cotton 1954; Kershaw 1991; Smith 1992; Gerber 1996; Stanisic 1998b). Barker (1999) rejected records of this species from New Zealand, identifying the material as *V. excentrica* Sterki, 1893.

Distribution in SA (Map 5): Recorded from W. Cape (Beaufort West, Cape Town, the Cape Peninsula and Vredendal), E. Cape (Dordrecht, Grahamstown, King William's Town, Port Elizabeth, Somerset East, Ugie), KwaZulu-Natal (Pietermaritzburg), Free State (Sasolburg) and Gauteng (Bryanston, Germiston, Johannesburg and Pretoria). Also known from Tsumeb, Namibia (W. Sirgel pers. comm.).

Pest status: Probably insignificant due to its small size and its diet of primarily dead vegetable matter, but see introduction to family. Known to serve as an intermediate host for nematode parasites of sheep (Samson & Holmes 1985).

Similar indigenous species: None. The small, flattened, white shell with its thickened, abruptly flaring lip is characteristic (but see *V. costata* above).

Notes: Connolly (1912) recorded *V. excentrica* from South Africa, but subsequently (Connolly 1939) changed his mind regarding the identity of the specimens available to him, referring them instead to *V. pulchella*. Gerber (1996) likewise identified smooth *Vallonia* specimens from South Africa as *V. pulchella*. I follow these authors, at the same time acknowledging that the two species are extremely similar and that the taxonomy of the group is not fully resolved (Barker 1999). *V. excentrica* reportedly has a more elliptical shell with a less acutely flaring aperture lip. Although some authors interpret these differences in shell form as merely being morphological plasticity or eco-phenotypic variation within a single species (Pakiet 1994), recent molecular evidence suggests that *V. excentrica* and *V. pulchella* are genuinely distinct, and moreover, that *V. excentrica* may in fact be a paraphyletic taxon (Korte & Armbruster 2003).

Family: Vertiginidae Fitzinger, 1833

***Vertigo ?antivertigo* (Draparnaud, 1801)**

(marsh whorl snail)

Figure 13

Pupa antivertigo Draparnaud 1801: 57.

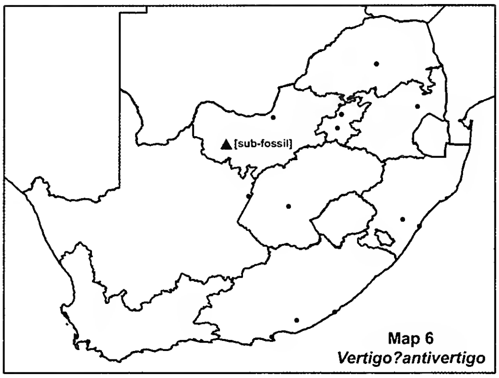
Vertigo antivertigo; Gardner 1935: 486, pl. 30, figs 31–35; Connolly 1939: 403; Quick 1952: 183; Van Bruggen 1964: 163.

Vertigo cf. *antivertigo*; Huckriede & Venzlaff 1962: 101, pl. 11, fig. 15.

Type loc.: France.

Notes: This widespread Euro-Siberian species has been recorded in southern Africa only in subfossil form (Connolly 1939), from Tlapings Laagte [?Tlapeng] in the Vryburg area, North West Province. An adequate explanation for this has not been given and Quick (1952) considered it a puzzle. It is possible that its natural distribution was once much more extensive, and that it has subsequently become extinct in sub-Saharan Africa. Additional subfossil material has evidently been found at Florisbad and Jagersfontein in the Free State (W. Sirgel pers. comm.). That a small snail such as this could have had an extremely wide natural distribution is not surprising and many still do. Today, the species is known to favour wet habitats which

FIGURE 13.—*Vertigo ? antivertigo* (Draparnaud, 1801), Mauerkirchen area, Bavaria, Germany, length 2.0 mm (NMSA F4802).



do not dry up for part of the year (Pokryszko 1990; Kerney 1999), suggesting, if the Tlapings Laagte subfossils are correctly identified, that parts of the North West Province were substantially wetter in the past. However, it is extremely unlikely that a wetland species such as this could survive today in what is a relatively arid region (mean annual precipitation 400–600 mm) with highly seasonal rainfall (Schulze 1997). It has also been found in Pleistocene pluvial deposits in now arid parts of Egypt (Gardner 1935) and Sudan (Huckriede & Venzlaff 1962). Further information on the species can be found in Pokryszko (1990).

A similar anomaly is presented by *Zonitoides africanus* Boettger, 1910, a species described as a subfossil from Gobabis in Namibia and recorded also from Tlapings Laagte. Connolly (1939) noted that this material was indistinguishable from the European *Zonitoides nitidus* (Müller, 1774). If this is so, it represents another curious example of a European species occurring as a subfossil in the Tlapings Laagte deposits.

Family: Achatinidae Swainson, 1840

A speciose family containing the largest terrestrial snails in the world. Native to Africa and its off-shore islands. Several species are important agriculturally, both as pests and as a food resource. The broad, high-spired shells are readily identified to family, but determination of species is complicated by unresolved taxonomic problems and intraspecific variability. There are more than 40 species indigenous to southern Africa, but most of these are quite distinct from the one recorded alien achatinid and are of little agricultural significance (with the possible exception of *Achatina immaculata* Lamarck, 1822). As recommended by Cowie *et al.* (2009) in relation to the USA, quarantine officials should maintain vigilance for any achatinids entering South Africa.

Achatina fulica Bowdich, 1822

(giant African snail)

Figure 14

Achatina fulica Bowdich 1822: pl. 13, fig. 3; Connolly 1912: 194; 1916: 188; 1939: 325; Bequaert 1950: 50; Van Bruggen 1964: 163.

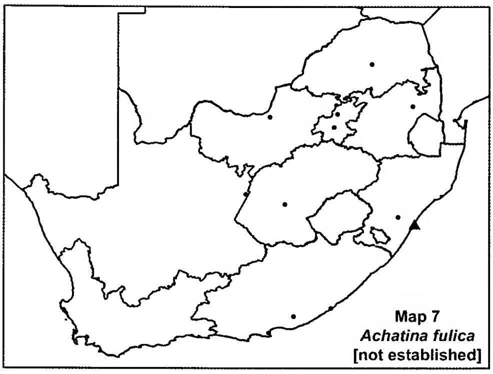
Type loc.: Not given by Bowdich, but probably Mauritius (where it is introduced) and designated such by Bequaert (1950: 63).

Description: Shell large to very large, elongate with a high spire, but height of aperture generally more than half shell length; sutures relatively strongly indented; coloration variable, seen through the yellowish brown periostracum of fresh specimens the colour pattern frequently comprises rather fuzzy-edged brown axial bands (sometimes zig-zag) on a yellowish brown ground (dirty white without periostracum); inner lip of aperture white. Maximum adult length 100–140 mm, exceptionally to 180 mm. Coloration and size dependent on environmental parameters and genetic make up of original source.

Habitat: A tropical species preferring warm, humid conditions; tolerant of a wide variety of habitats including transformed ones. May climb vegetation.

Date of introduction: *Circa* 1900. Discussing this species in 1916, Connolly stated that Henry Burnup had received the specimen concerned some 15 years previously.

FIGURE 14.—*Achatina fulica hamillei* Petit, 1859, Zanzibar, length 112 mm (NMW Z1981.1180).



First SA record: Connolly (1912), Durban, KwaZulu-Natal; record based on a single live juvenile specimen thought to have been imported from Mauritius amongst plant material.

Global distribution: Native to East Africa, extending south to the Zambesi River (Bequaert 1950) and perhaps further, but the limits of its original distribution are now difficult to determine. Although the type locality is Mauritius, it is not thought to be an indigenous inhabitant of the island (Griffiths & Florens 2006). Introduced widely in tropical regions around the world.

Distribution in SA (Map 7): Recorded from Durban, but no established colonies now evident in South Africa.

Pest status: A hugely problematic pest in the many tropical countries in which it has become established (Mead 1961, 1979; Raut & Barker 2002) and continues to spread rapidly in areas to which it is newly introduced (Thiengo *et al.* 2007), often after an initial lag phase. Ranked amongst the top 100 of the world's worst invasive species (IUCN–ISSG 2000). Also know as an intermediate host and important dispersal agent for the rat lungworm *Angiostrongylus cantonensis*, which causes eosinophilic meningitis in humans (Kliks & Palumbo 1992).

Similar indigenous species: The indigenous *Achatina immaculata* Lamarck, 1822, widely distributed in the northeastern regions of South Africa and in countries to the north, is very similar. It differs most notably in that the inner lip is covered with a pink callus glaze. *A. fulica* is also generally more slender than *A. immaculata*.

Notes: This species, the so-called 'giant African snail', has spread extensively from its original East African home (detailed discussion of this topic is beyond the scope of this review). It has fared particularly well on tropical islands, where our own attempts to eradicate it by introducing carnivorous snails have proved disastrous for the endemic snail fauna. This is now a classic worst-case scenario example of what can go wrong when biological control methods are ill-conceived and inadequately researched or when the authorities fail to take heed of the advice given to them (Civeyrel & Simberloff 1996; Cowie 1992, 2001a; Coote & Loéve 2003). Evidence now available suggests that the dense populations that occur after introduction sometimes subsequently undergo a period of marked decline (Cowie 2001a; Simberloff & Gibbons 2004), perhaps mediated by parasites, microbial pathogens or inbreeding depression due to limited genetic diversity, or a combination thereof, and that biocontrol initiatives using introduced predators (e.g. *Euglandina rosea*), despite the unproven claims of proponents, have largely been ineffective. Recent evidence indicates that *A. fulica* is also partially predatory and that it will kill and consume living molluscs (Meyer *et al.* 2008). The species itself therefore represents a potential threat to the indigenous molluscan fauna in areas to which it has spread.

That *Achatina fulica* has not, of its own accord, spread south from East Africa into southern Africa indicates that there is an environmental or biological barrier of some

kind in natural habitats that prevents this. However, this does not negate the possibility of viable colonies becoming established, particularly in the highly transformed urban and agricultural habitats along the eastern seaboard, as a result of future human-mediated translocations. Smith (1992) noted that specimens are intercepted constantly by quarantine officials at all major ports in Australia. Elsewhere in Africa, the species is recorded as an introduction in Côte d'Ivoire (De Winter 1988a, 1989; Otchoumou *et al.* 2005), Ghana (Monney 1994) and Morocco (Van Bruggen 1987b).

Family: Ferussaciidae Bourguignat, 1883

Small snails with very slender, thin shells; apex blunt; smooth and glossy, colourless and almost transparent when alive. Generally blind and largely subterranean; herbivorous, thought to feed on decaying plant material, fungi and perhaps fine roots. Members of the family may be found in many parts of the world, with three indigenous species occurring in southern Africa and one dubious record of an introduced species.

Cecilioides acicula (Müller, 1774)

(blind pin snail)

Figure 15

Buccinum aciculum Müller 1774: 150.

Caecilianella acicula; Melvill & Ponsonby 1898: 184;

Caecilioides acicula; Connolly 1912: 206; 1916: 188.

Cecilioides acicula; Connolly 1930: 297; 1939: 368, pl. 8, fig. 12; Quick 1952: 188; Van Bruggen 1964: 163; Van Bruggen & Van Goethem 2001: 156, figs 10, 11.

Type loc.: Thuringia—Thangelstedt near Weimar, Germany.

Description: Shell slender with a blunt apex and relatively few, elongate whorls; smooth and glossy; glassy when fresh, becoming opaque white after death; aperture narrow, outer lip and parietal lip flattened, columella strongly concave and distinctly truncated at its base. Length up to 5.5 mm.

Habitat: In Europe *Cecilioides acicula* favours open (grassy) habitats on calcareous

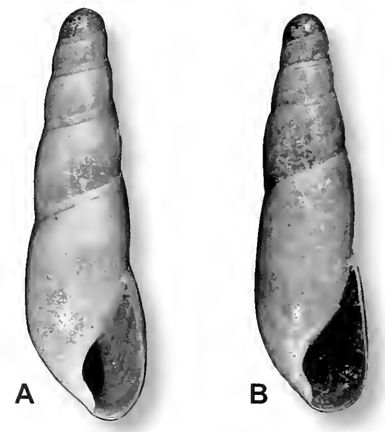
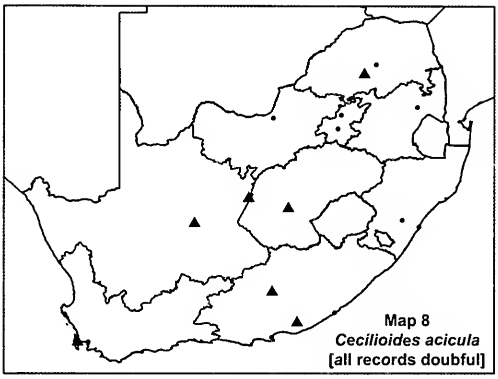


FIGURE 15.—*Cecilioides*. A, *Cecilioides acicula* (Müller, 1774), France, length 4.2 mm (NMSA F4808); B, *Cecilioides* sp. Grahamstown length 4.2 mm, (NMSA V2717 [undated, but pre 1980]).



soils, where it may be found as much as two metres below ground (Kerney 1999); often associated with bones and graveyards.

Date of introduction: Introduction not confirmed (see notes below).

First SA record: Melvill & Ponsonby (1898), Cradock, E. Cape.

Global distribution: Thought to be of Mediterranean origin (Kerney 1999), but now widespread through human agency in Europe and introduced to many other parts of the world, including North America (Robinson 1999), Uruguay (Scarabino 2003), Bermuda (Bieler & Slapcinsky 2000), the Azores (Backhuys 1975), Madeira (Seddon 2008), St Helena (Crowley & Pain 1977) and New Zealand (Barker 1999). Some records probably based on misidentifications (Chase & Robinson 2001).

Distribution in SA (Map 8): Recorded from W. Cape (Cape Town, Wynberg), E. Cape (Cra-

dock, Grahamstown), N. Cape (Kimberley, Prieska), Free State (Bloemfontein), Limpopo (Potgeitersrus [now Mokopane]), and also from a number of sites in northern Namibia (Damaraland, Etosha and Kaokoland). However, the identity of all the material in question is uncertain (see notes below).

Pest status: Unlikely to be problematic.

Similar indigenous species: All local *Cecilioides* species.

Notes: Connolly (1912, 1939) and (Quick 1952) recorded *C. acicula* from widely scattered localities in southern Africa, mostly in the drier regions, including Namibia. However, in discussing the indigenous *C. advena* (Ancey, 1888), Connolly (1939) noted that this was extremely similar to South African material identified as *C. acicula* and raised the possibility that the latter may be incorrectly identified. Subsequently, Van Bruggen (1964) omitted *C. acicula* from his list of South African alien non-marine molluscs on the grounds that the status and affinities of the material were not sufficiently clear. Later, he seemed to accept the record as genuine (Van Bruggen & Van Goethem 2001). My own experience of ferussaciid molluscs in South Africa leads me to remain sceptical about the occurrence of *C. acicula* in this country. The morphological limits of the various nominate species are not clearly defined and there appears to be considerable variation within populations. The family as a whole requires more detailed study. In the meantime, I believe it likely that most of the material discussed under this name by Connolly (1939) belonged to indigenous species, with the possible exception of specimens from gardens in Grahamstown and Wynberg, Cape Town, areas known to contain a range of other European aliens. These uncertainties will probably remain until the matter is investigated using DNA sequence data.

Further details regarding the biology of *C. acicula* were provided by Wächtler (1929a, b).

Family: Subulinidae Fischer & Crosse, 1877

A large, primarily tropical family of snails, usually possessing slender, many-whorled, awl-like shells of a uniform colour. Numerous indigenous members of the family occur in southern Africa, inhabiting a wide variety of environments, generally living in accumulations of leaf litter in sheltering microhabitats and beneath logs and stones, often below the soil surface. Two introduced species have been recorded in South Africa, namely *Rumina decollata* and *Subulina octona*. These do not appear to have become established here, but *S. octona* has evidently become so in Zimbabwe.

Subulinds are primarily herbivorous, feeding on living and dead plant material, and detritus, but may also scavenge on dead animal material. Occasionally minor pests in greenhouses, nurseries and gardens, but generally not problematic (Solem 1998). However, the genus *Rumina* is partially predatory, feeding on other molluscs, and has been promoted as a biocontrol agent for *Cornu aspersum* and other helicid snails in California, despite the fact that it may itself become a plant pest (see below). A number of small species are considered invasive in tropical regions and may possibly displace indigenous snails (see potential future introductions below).

Rumina decollata (Linnaeus, 1758)

(decollate snail)

Figure 16

Helix decollata Linnaeus 1758: 773.

Rumina decollata; Melvill & Ponsonby 1898: 184; Connolly 1912: 285; 1916: 189; 1939: 632.

Type loc.: Southern Europe.

Description: Shell of moderate size, long and slender, but adults with apex missing (decollate), shell thus appearing broken, only the last 3–6 whorls remaining; resultant hole at apex sealed over with shelly septum; whorls rather flat-sided and suture shallowly indented; slightly glossy, sculptured mostly by irregular growth-lines, strongest just below suture, and occasionally with weak spiral lines; umbilicus chink-like, almost closed by callus of inner lip. Uniformly whitish to dirty buff or pale apricot. Adult length typically 20–30 mm; shell proportions highly variable (compare Figure 16, C and D).

Habitat: *Rumina decollata* generally favours rather dry places and calcareous soils in its native range, often occurring in waste ground, disturbed habitats and dry scrubby or rocky terrain (Kerney & Cameron 1979; Moreno-Rueda 2002). Selander & Kaufman (1973) reported it to be common in gardens and agricultural areas in Texas, and to have invaded riparian and other native habitats.

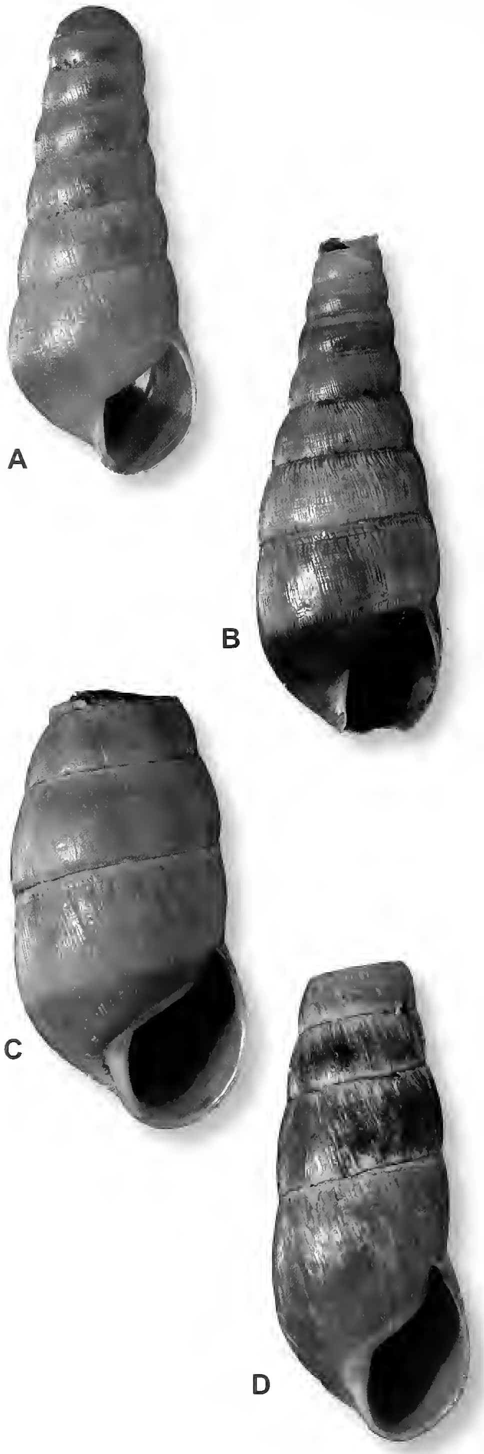
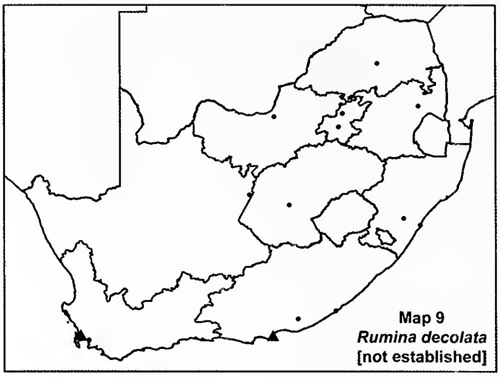


FIGURE 16.—*Rumina decollata* (Linnaeus, 1758). A–C, Santa Colomba, Siena area, Tuscany, Italy (NMSA L5636 [2001]): A, juvenile, length 13.5 mm; B, subadult, length 27.9 mm; C, adult, length 23.5 mm; D, Monte Vista, Cape Town, length 26.0 mm (NMSA S5188 [1992]).



Date of introduction: Prior to 1897 (Connolly 1912), but see notes below.

First SA record: Melvill & Ponsonby (1898) recorded the species from 'Pondoland', but this presumably refers to the same material that Connolly (1912) cited as originating in Port Elizabeth, E. Cape (*ex* Layard) [now in the South African Museum, Cape Town].

Global distribution: Native to the Mediterranean. Introduced also to most southern states of the USA (California to Florida) (Pilsbry 1946; Fisher 1966, 1974; Dundee 1970; Mead 1971b), Cuba and Mexico (Mead 1971b), Argentina (Miquel 1988), Brazil (Simone 2006), Uruguay (Scarabino 2003), Bermuda (Bieler & Slapcinsky 2000), Azores (Backhuys 1975), Madeira (Seddon 2008), Britain (Seddon & Pickard 2005), Israel (Singer & Mienis 1993; Roll *et al*. 2009), China (Beckmann 1989; Chang & Chung 1993) and Japan (Mashino 1992; Minato & Uozumi 1992; Hosaka 1996).

Distribution in SA (Map 9): Known only from the original Port Elizabeth material and more recently in Monte Vista, Cape Town in 1992. Not established in Port Elizabeth and eradicated in Cape Town.

Pest status: Uncertain, but in other parts of the world populations can evidently reach high densities and become a nuisance, if not a pest. Mead (1979) reported densities in excess of 80 000 snails per acre in Arizona. Although *Rumina decollata* is partly carnivorous (see notes below), it is known to eat the tender young shoots of seedlings. Bieler & Slapcinsky (2000) considered it a pest in Bermuda. The species is also known to serve as an intermediate host for *Brachlaima* trematode parasites of rodents (Mas-Coma & Montoliu 1986). Beyond the agriculture/horticulture sector, it may also represent a conser-

vation concern due to its potential impact on indigenous species (Cowie 2001a).

Similar indigenous species: Some of the larger awl snails from èastern South Africa are similar, but the habit of deliberately losing the shell apex in adults is characteristic of *R. decollata*. In addition the body of *R. decollata* is dark brown to blackish, whereas all our local subulinids have a much paler, often bright yellow body.

Notes: Connolly (1912) dismissed the original 1897, Port Elizabeth record, believing it to be based on material that had been imported dead, but at the same time feared that a second and more successful introduction would in due course occur. However, no further specimens came to light until a living colony was discovered in a garden in the Monte Vista suburb of Cape Town in 1992. This was brought to the attention of Dr Willem Sirgel (University of Stellenbosch), who in turn notified the Chief Directorate, Department of Agriculture—Winter Rainfall Area. Prompt action ensued and the colony was eliminated and there have been no subsequent records.

Rumina decollata is at least partially predatory and is known to eat other snails. In parts of California, where it was first discovered in 1966 (Fisher 1966), it is now sold as a biocontrol agent for the brown garden snail, *Cornu aspersum*, and its use there is advocated as part of integrated pest management practice (Burch 1989; Sakovich 1996, 2002), particularly for citrus and avocado crops, though not without some reservations (Tupen & Roth 2001). However, the evidence for its efficacy in the control of *C. aspersum* is to date circumstantial. The issue has not been rigorously investigated and no causal relationship between *R. decollata* introduction and *C. aspersum* decline has been demonstrated (Cowie 2001a). Similarly, the impact of the snail on indigenous species has also not been examined and, as a result, the greatest caution should be exercised with regard to the possible use of *R. decollata* as a predator of pest snails in South Africa. Authorities in California now only sanction its sale and use for biocontrol in counties where it is already known to exist. Using predatory snails as biocontrol agents for pest snails in other parts of the world has back-fired spectacularly in the past, with indigenous snails suffering much more than the pest ones, to the extent that some are now extinct (see *Achatina fulica* above and Cowie 2001a; Coote & Loéve 2003).

Since *R. decollata* is of Mediterranean origin and much of the southwestern Cape has a 'Mediterranean' climate, introduced populations might spread rapidly and could easily get out of control, quite possibly to the detriment of our indigenous species. Its spread may be further facilitated by its ability to self-fertilise, creating monogenetic populations (Selander & Kaufman 1973; Selander *et al.* 1974). In Argentina, where it was first recorded in 1988, it has dispersed more than 1 000 km from the original source (De Francesco & Lagiglia 2007). The species is now very common in parts of Japan (Matsukuma in lit. 2006).

It is almost certainly not coincidental that the finding of the colony of *Rumina decollata* in Cape Town in 1992 followed a number of enquiries regarding the possible use of this species for biocontrol purposes in South Africa (W. Sirgel pers. comm.). Given the evidence available, such an option must be strongly rejected. Unfortunately, these snails are now being offered for sale as supposedly effective biocontrol agents, by electronic mail order. Consumers, unaware that *R. decollata* can itself become a plant pest, could easily unwittingly introduce them to countries in which they are not currently known to occur.

Dundee (1986) observed that the eggs are laid in hollows in the soil, the clusters containing anything between 7–64 individual eggs. Two periods of egg-laying occur each year, in late winter to early summer and again during the autumn. Hatching time varies from 9–30 days, depending on temperature. Subsequent growth is rapid, the snails reaching maturity at about 10 months, with most dying when about one year old. Loss of the uppermost spire whorls (decollation) occurs when the snails are 10–15 mm long (Kat 1981; Dundee 1986).

Until recently, the genus *Rumina* was considered to contain only one species, *R. decollata*. However, Bank & Gittenberger (1993) and Carr (2002) recently recognised a further species, *R. saharica* Pallary, 1901, which generally has a narrower shell and differs in terms of the internal anatomy of the penis. This is evidently supported by preliminary DNA data (Prévot *et al.* 2007). Although no preserved material is available for South African *Rumina* specimens, the proportions of the shell accord with those of *R. decollata*. Mienis (2002, 2008) has pointed out the existence of a third species, the much larger *R. paviae* (Lowe, 1861) from North Africa.

Subulina octona **(Bruguière, 1789)**

(wandering awl snail)

Figure 17

Bulimus octonus Bruguière 1789 in 1789–92: 325.

Subulina octona; Connolly 1912: 210; 1916: 189; 1939: 332; Germain 1920: 120; Van Bruggen 1964: 162.

Type loc.: 'Les Îles Antilles' [Caribbean].

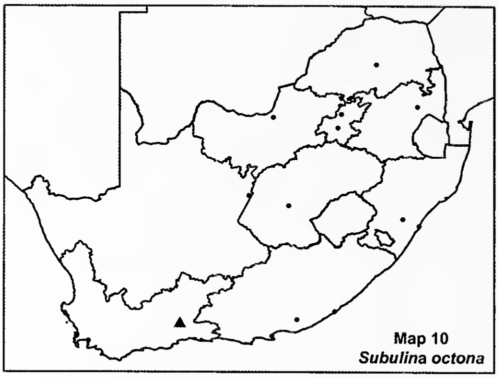


FIGURE 17.—*Subulina octona* (Bruguière, 1789), Victoria Falls, Zimbabwe, length 13.5 mm (NMSA G9268 [undated]).

Description: Shell small to medium-sized, long and slender, tapering slowly toward apex with 8–9 rather squat, strongly convex whorls; apex bluntly rounded and relatively large; aperture small, base of columella truncated and curving to left before joining basal lip; somewhat glossy and smooth save for microscopic growth-lines, which cause a slight, irregular crenulation of the suture; umbilicus lacking. Translucent, uniformly straw yellow when fresh. Length rarely more than 17 mm, exceptionally up to 22 mm.

Habitat: *Subulina octona* favours moist places, living in superficial soil litter, under stones, logs and amongst dead vegetation, particularly in disturbed areas; also in hothouses (Kerney & Cameron 1979; Smith 1992; Cowie 1997; Bieler & Slapcinsky 2000).

Date of introduction: Prior to 1913 (Cango Caves), but Zimbabwe material dates from 1905 (Dixey & Longstaff 1907).

First SA record: Germain (1920), Cango Caves, Oudtshoorn area, W. Cape.

Global distribution: Described from the Caribbean (Antilles) and traditionally considered native to tropical America. The latter fact recently questioned by Bieler & Slapcinsky (2000). Rosenberg & Muratov (2006) and Simone (2006) considered it introduced in Jamaica and Brazil respectively, whilst Gerlach (2006) believed it to be indigenous in the Seychelles. Now occurs widely in other parts of the world, including many USA states (Dundee 1974), the Bahamas (Deisler & Abbott 1984), Bermuda (Bieler & Slapcinsky 2000), Britain (Kerney & Cameron 1979), tropical Africa, Madagascar and smaller Indian Ocean islands (Fischer-Piette & Vukadinovic 1974; Griffiths 1994; Griffiths & Florens 2006), India (Mitra *et al.* 2005), Australia (Solem 1988), New Caledonia (Solem 1964), Hawaii (Cowie 1997), Samoa (Cowie 1998b) and many other islands in the Pacific (Preece 1995; Cowie 2000).

Distribution in SA (Map 10): Recorded in southern Africa only from Cango Caves, near Oudtshoorn (W. Cape) and Victoria Falls (Zimbabwe). No further material has come to light from the Oudtshoorn area (or anywhere else in South Africa), but additional specimens are known from Victoria Falls.

Pest status: Considered a garden pest in northern Australia where it can be abundant (Solem 1988), but generally not regarded as a particularly problematic species. Thought to be a detritus feeder, mostly consuming dead

vegetable matter (Smith 1992), and thus perhaps playing a role in nutrient recycling. May serve as an intermediate host for *Postharmostomum gallinum*, a trematode parasite of domestic chickens (De Faria Duarte 1980).

Similar indigenous species: More than 50 indigenous species of the family Subulinidae are known from South Africa. Many of the smaller ones closely resemble *S. octona* and distinguishing them requires some experience. Most have fewer and/or more elongate whorls, a less deeply indented suture and lack the characteristically truncate columella base of *Subulina*, and are referred to other genera. In indigenous species of *Subulina* the apex of the shell is distinctly narrower than it is in *S. octona*.

Notes: *Subulina octona* is a circum-tropical tramp which has successfully colonised disturbed habitats in many tropical countries and islands, as well as greenhouses in colder climates (e.g. Britain). In some countries (e.g. Australia) it has spread beyond gardens and ruderal habitats into the native vegetation (Solem 1998). The warm moist environment around Victoria Falls is probably well suited to this species and the population there seems to be self-sustaining. It is less likely that this would be the case in the Oudtshoorn area. However, the possibility that this species could establish itself in coastal KwaZulu-Natal or the lowveld of Mpumalanga and Limpopo remains. Likewise it could become a greenhouse alien in the Cape.

Family: Discidae Thiele, 1931

Small snails with a widely umbilicate, low-spired shell and narrow, rather tightly coiled whorls; frequently with marked axial sculpture; aperture lacking teeth. The family is native to the northern hemisphere and comprises relatively few species; herbivorous or detritivorous. This group of snails has frequently been included as a subfamily within the much larger Endodontidae (e.g. Kerney & Cameron 1979), but the late Alan Solem, an expert on the latter, believed the Discidae to be sufficiently distinct as to warrant recognition as a separate family (Solem 1983). Molecular evidence supports this distinction (Wade *et al.* 2006). The family name Discidae has been accorded precedence over the older, but little used Patulidae (Bouchet & Rocroi 2005).

Discus rotundatus (Müller, 1774)

(rounded snail, spotted disc, rotund disc)

Figure 18

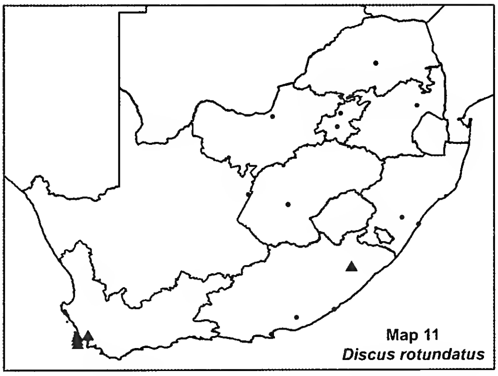
Helix rotundata Müller 1774: 29.

Type loc.: Frederiksdal, near Copenhagen, Denmark.

FIGURE 18.—*Discus rotundatus* (Müller, 1774), Claremont, Cape Town, diameter 5.0 mm (NMSA V9232 [2001]).

Description: Shell small, somewhat flattened, comprising 5.5–6.5 tightly coiled whorls; whorls distinctly angled at periphery, flatter above this and more rounded below; suture strongly indented; periphery above mid-whorl; first two whorls ± smooth, remainder sculptured with numerous, strong, close-set, axial ribs; umbilicus wide and funnel-shaped; lip of aperture simple. Ground colour pale straw-brown, with axial bands of darker reddish brown, producing a characteristic pattern of alternating, more or less regularly spaced dark and light brown markings. Diameter of largest South African specimen 5.6 mm, but reaching 7.0 mm in Europe.

Habitat: In Europe *Discus rotundatus* can be found in sheltered locations almost anywhere; under logs and stones, amongst leaf litter and in garden refuse; tolerant of acidic conditions (Kerney 1999). As an alien in North America,



it is largely found in gardens, parks and greenhouses. In the W. Cape it has spread from suburban gardens into natural vegetation (shaded kloofs) in the Cape Peninsula National Park, and in the E. Cape it has been found in remote indigenous forests (see notes below).

Date of introduction: Prior to 1986 (Cape Town, W. Sirgel pers. comm.).

First SA record: Not previously recorded.

Global distribution: Native to western and central Europe, and southern Scandinavia. Introduced also to North America (Pilsbry 1948; Robinson 1999; Forsyth 2004), Madeira (Seddon 2008), Malta (Giusti *et al.* 1995) and southeastern Europe (Őrstan 2003), but evidently not widely introduced to other regions. Robinson (1999), however, considered it a travelling species.

Distribution in SA (Map 11): Recorded from W. Cape (Cape Peninsula, Claremont and Stellenbosch) and E. Cape (Mthatha area).

Pest status: Probably a detritivore and of little pest significance.

Similar indigenous species: Some indigenous charopid snails of the genus *Trachycystis* (pinwheel snails) may have similar axial ribs, but they are generally more uniform in colour. Only *T. prionacis* (Benson, 1864) from the southwestern Cape has similar rufous axial flames, but that species is somewhat smaller, has a stronger peripheral keel and a smoother base with a much narrower umbilicus than *D. rotundatus*.

Notes: During the five-year period 1993–1998, this species comprised over one percent of all alien snail interceptions at US ports of entry (Robinson 1999), indicating it to be a species relatively commonly translocated by human agency. Its recent discovery in the southwestern Cape is therefore not surprising and it may well have been present in the area for many years.

Although the finding of additional material in a remote indigenous forest west of Mthatha was unexpected, considerable habitat transformation has occurred in the area and the few indigenous forest patches that remain are often surrounded by exotic forestry plantations (mostly pine). *Discus rotundatus* is known to occur in coniferous woodland in Europe and its spread into indigenous forest in the E. Cape was doubtless mediated by the forestry industry (see also *Hawaiia minuscula*). The snail has almost certainly established itself at one or more sylviculture nurseries from which it has been dispersed to plantations and hence to neighbouring native habitats. Information on the life cycle of *D. rotundatus* was provided by Kuźnik-Kowalska (1999).

Family: Gastrodontidae Tryon, 1866

Until recently, species belonging to the next three families (Gastrodontidae, Oxychilidae and Pristilomatidae) were considered to belong to the family Zonitidae. However, most recent European authors now agree that Zonitidae *sensu lato* comprises several distinct family-level entities (Hausdorf 1998; Bank *et al.* 2001; Falkner *et al.* 2001, Anderson 2005; Bouchet & Rocroi 2005).

Gastrodontids are small snails which resemble members of the Oxychilidae (below), but differ in the detailed anatomy of the reproductive tract (Pilsbry 1946; Hausdorf 1998; Schileyko 2003).

Zonitoides arboreus (Say, 1816)

(orchid snail, quick gloss snail)

Figure 19

Helix arboreus Say 1816: species no. 2, pl. 4, fig. 4.

Zonitoides arboreus; Melvill & Ponsonby 1898: 184; Connolly 1912: 116; 1916: 183; 1939: 173; Van Bruggen 1964: 162; Herbert & Kilburn 2004: 273.

Type loc.: United States.

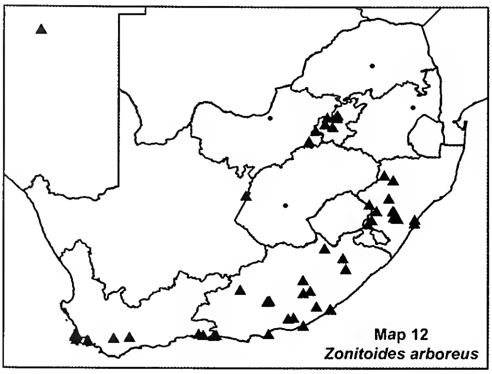
FIGURE 19.—*Zonitoides arboreus* (Say, 1816), Eucalyptus plantation, Hilton, KwaZulu-Natal, diameter 4.47 mm (NMSA W7077 [2009]).

Description: Shell small and relatively low-spired, but not as depressed as species of *Oxychilus*; 4.5–5.0 rather narrowly expanding whorls; suture remaining clearly indented; sculpture of close-set growth-lines and extremely fine spiral lines, the latter only just visible even under a microscope, otherwise smooth and glossy; umbilicus deep, initially wide, but narrowing sharply within. Translucent, pale honey-brown, darker when alive. Living animal with head and neck dark blue-grey dorsally, the tail and sides of the foot paler. Diameter up to 6.0 mm.

Habitat: Tolerant of a wide variety of habitats in its native range, including natural and transformed habitats—'wherever there are trees or shelter of any kind' (Pilsbry 1946). Most specimens in SA have been found in gardens and forestry plantations (eucalypt, pine and wattle), but it has also spread into adjacent natural habitats; under logs, flower pots and ground-cover plants, in leaf litter under trees and behind flaking bark.

Date of introduction: Prior to 1898.

First SA record: Melvill & Ponsonby (1898), Port Elizabeth, E. Cape.



Global distribution: Native to North America, but now introduced to many other parts of the world by human agency, including: Uruguay (Scarabino 2003), Brazil (Simone 2006), Jamaica (Rosenberg & Muratov 2006), Bermuda (Bieler & Slapcinsky 2000), Madeira (Seddon 2008), Britain (Kerney & Cameron 1979), Israel (Roll *et al.* 2009), Kenya (Verdcourt 1972), Madagascar (Testud 1965; Fischer-Piette *et al.* 1994), Mascarene Islands (Stévanovitch 1994; Griffiths 1994; Griffiths & Florens 2006), Russia (Pilsbry 1946), Japan (Ueshima *et al.* 2000), Hong Kong (Brandt 1980), Australia (Bishop 1978), New Zealand (Barker 1999), Hawaii (Cowie 1997) and islands in the south Pacific (Preece 1995; Cowie 2000).

Distribution in SA (Map 12): Known from widely scattered localities across the country. Many records from W. Cape, E. Cape, KwaZulu-Natal and Gauteng, with additional localities in N. Cape and N.W. Province. Although most records, even those from rural areas, are still largely associated with human habitation or transformed land, specimens have been found in the indigenous forest associated with tourist spots in the Knysna area and around Pietermaritzburg. Also recorded from Namibia (Windhoek and Tsumeb) (Van Bruggen & Rolán 2003 and W. Sirgel pers. comm.)

Pest status: A common green-house pest in many parts of the world and reportedly a particular problem for orchid growers, since it eats the root tips, leaves and flowers (Verdcourt 1979; Mienis 1980; Barker 1999; Hollingsworth *et al.* 2003). In the USA it has also been identified as a root pest of sugar cane (Bartsch & Quick 1926) and as a vector for sugar cane root rot (Rands 1924). Known to serve as an intermediate host for cestode parasites of birds (Dick & Burt 1971).

Similar indigenous species: Resembles some of the numerous small indigenous species of *Trachycystis* (Charopidae), but is more glossy. *Thapsia pinguis* (Krauss, 1848) (Urocyclidae) from forest and mixed bushveld habitats is also similar, but has a narrower umbilicus with spiral lirae inside and occurs locally only in the north-eastern parts of the country (Herbert & Kilburn 2004).

Notes: *Zonitoides arboreus* is clearly a highly successful colonist and has spread widely in South Africa. Although it prospers under synanthropic conditions, it is not confined to these and may be common in transformed habitats in general. In exotic forestry plantations it may be particularly abundant, reaching population densities of hundreds of snails per square metre (pers. obs.). It is probable that the species is established in many local garden centres and sylviculture nurseries, from which it is dispersed widely with the plants and tree saplings. In addition, there has clearly been some spread from transformed habitats into neighbouring indigenous ones.

The smaller size, higher spire, more narrowly expanding whorls and more prominent sculpture distinguish this species from the introduced *Oxychilus* species. Capable of self-fertilisation (Barker 1999; Hollingsworth *et al.* 2003).

Family: Oxychilidae Hesse, 1927

Oxychilid snails typically have low-spired, somewhat lens-shaped shells that are thin and often translucent or glassy. All species occurring in South Africa are introduced. Since many are at least partly carnivorous and do not feed on green plants, they pose little threat as pests in the agriculture/horticulture sector, and may in fact make a positive contribution by consuming other soft-bodied invertebrates including pest snails and their eggs, and insect larvae. However, their effect on the indigenous molluscan fauna in areas to which they have been introduced is not well studied. They have the potential to impact negatively on indigenous species if natural habitats are invaded, as has been suggested for *Oxychilus alliarius* in Hawaii (see below) and for *O. draparnaudi* in Iowa, USA (Frest & Rhodes 1982).

Species of *Oxychilus* are notoriously difficult to distinguish when only the empty shell is available. The coloration of the living animal provides important additional characters facilitating identification (see below) and Lloyd (1970a) has also shown that skin characters of the head/neck region are also diagnostic. It is therefore difficult to identify or confirm the identity of old museum specimens with certainty. Consequently, the distribution records given below may not be entirely accurate. This problem is not currently of great importance since none of the species has spread extensively.

Aegopinella nitidula (Draparnaud, 1805)

(smooth glass snail, waxy glass snail)

Figure 20

Helix nitidula Draparnaud 1805: 117.

Type loc.: France.

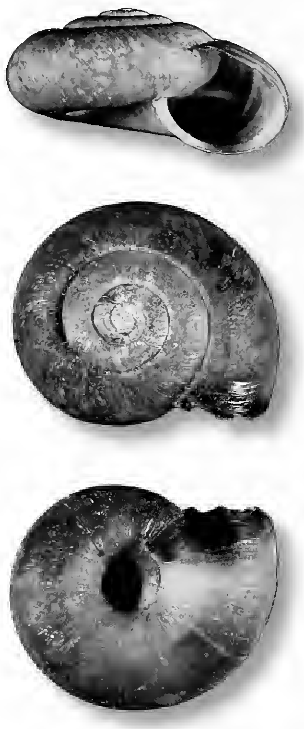
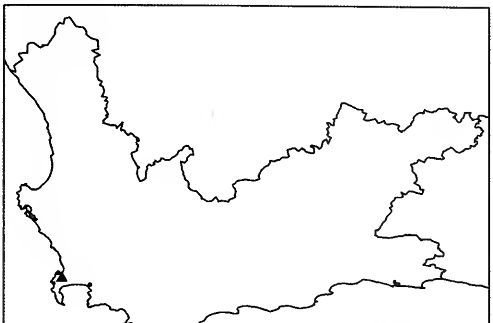


FIGURE 20.—*Aegopinella nitidula* (Draparnaud, 1805), Rondebosch, Cape Town, diameter 6.9 mm (NMSA A9773 [pre 1930]).

Description: Shell disc-like, consisting of ± 4.5 flattened, more or less evenly expanding whorls; smooth, but surface waxy rather than glossy on account of numerous extremely fine, close-set spiral striae; faint growth-lines present near suture; umbilicus wide; slightly



Map 13
Aegopinella nitidula

translucent, light horn-brown, sometimes tinged reddish, occasionally white. Diameter of largest South African specimen 7.2 mm, but up to 10.0 mm in Europe. Animal dark grey dorsally and paler laterally; sole pale.

Habitat: A widely tolerant species in Europe, living in shaded locations in a range of generally damp habitats, including deciduous and coniferous woods, gardens, hedgebanks and moist grassland (Mordan 1977; Kerney 1999; Kileen 1992). The only South African material known was collected in a suburban garden.

Date of introduction: Prior to 1930; material in NMSA was donated by Connolly in 1930.

First SA record: Not previously recorded.

Global distribution: Native to northwestern and central Europe, and the Azores (Riedel 1980), but evidently not widely introduced to other regions. The only other confirmed record of its occurrence as an alien, of which I am aware, is one from Canada (Forsyth *et al.* 2001; Forsyth 2004).

Distribution in SA (Map 13): Known only from one sample collected in Rondebosch, Cape Town, W. Cape.

Pest status: Probably insignificant.

Similar indigenous species: *Thapsia pinguis* (Krauss, 1848) (Urocyclidae), which occurs in northeastern South Africa and has similar microscopic spiral sculpture, has a much narrower umbilicus with distinct spiral threads inside.

Notes: Shells of *Aegopinella* species differ from those of *Oxychilus* (below) in that the surface has a waxy sheen (glossy in *Oxychilus*) as a result of microscopic spiral sculpture. The South African material considered here closely resembles *A. nitidula* (R. Preece pers. comm.), but since the various species of *Aegopinella* can only be reliably distinguished by dissection of the distal genital tract, this identification must be considered provisional. Further information on species discrimination can be found in Kerney & Cameron (1979) and Kerney *et al.* (1983). Mordan (1977, 1978) has discussed aspects of the biology and life cycle and of *A. nitidula*. It is primarily herbivorous, but will prey on small snails and slugs and earthworms (Forsyth *et al.* 2001).

Genus *Oxychilus* Fitzinger, 1833

Guide to identification of *Oxychilus* species recorded in South Africa.

- ***O. alliarius***—shell relatively small (diameter up to 7 mm), generally of a richer (deeper) brown colour; animal dark, blue-black to almost black; emits pungent garlic smell when disturbed.

- ***O. cellarius***—shell of moderate size (diameter up to 9–12 mm), pale horn-brown/yellow in colour; animal usually pale blue-grey, mantle edge speckled/spotted with grey/brown.

- ***O. draparnaudi***—shell relatively large (diameter up to 16 mm), pale horn-brown; animal blue-grey, mantle edge dark, lacking spots.

Additional characters relating to gland cells and epithelial pits in the skin of the head/neck region were provided by Lloyd (1970a) and to the distal genital tract by Giusti & Manganelli (1997).

Oxychilus alliarius (Miller, 1822)

(garlic glass snail)

Figure 21

Helix alliaria Miller 1822: 379.

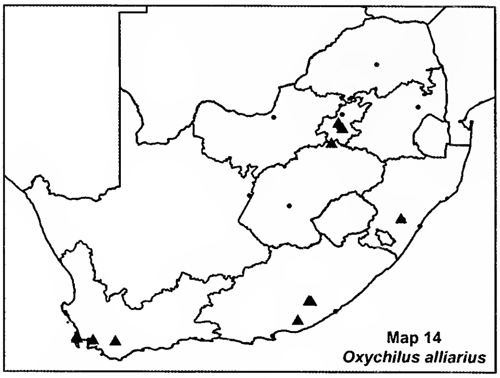
Polita alliaria; Connolly 1912: 112; 1916: 182.

Oxychilus alliarius; Connolly 1939: 171; Quick 1952: 188; Van Bruggen 1964: 162; Herbert & Kilburn 2004: 273.

Type loc.: The environs of Bristol, England.

Description: Smaller than *O. draparnaudi* and *O. cellarius* (diameter 5.5–7.0 mm) and with fewer whorls (4.0–4.5); umbilicus somewhat eccentric (axis off-centre); honey-brown.

FIGURE 21.—*Oxychilus alliarius* (Miller, 1822), Grahamstown, E. Cape, diameter 7.4 mm (NMSA S2678 [undated]).



Head-foot of living animal slate-grey to blue-black. Smells strongly of garlic when handled.

Habitat: Widely tolerant in its native range, living in sheltered locations in a range of habitats, including acidic ones such as conifer plantations (Kerney 1999; Killeen 1992); under logs and stones, amongst hedgebank vegetation, beneath ground-cover plants and in leaf litter. Most South African records are from gardens and disturbed land, but has been found in indigenous forest in the Pietermaritzburg area.

Date of introduction: Prior to 1894 (Connolly 1916).

First SA record: Connolly (1912), Grahamstown, E. Cape.

Global distribution: Native to western Europe. Introduced also to North America, (Robinson 1999; Forsyth 2004), South America (Stuardo & Vega 1985; Smith 1989; Hausdorf 2002), Madeira (Seddon 2008), St Helena (Crowley & Pain 1977), islands of the South Atlantic (Preece 2001), Réunion (Stévanovitch 1994; Griffiths & Florens 2006), Sri Lanka (Naggs *et al.* 2003), S.E. Australia (Laws 1966; Smith 1992), Tasmania (Kershaw 1991), New Zealand (Barker 1999) and Hawaii (Cowie 1997).

Distribution in SA (Map 14): Recorded from W. Cape (Cape Town area, Hottentots Holland and Riviersonderend Mountains), E. Cape (Grahamstown and Hogsback), Free State (Sasolburg), Gauteng (Bryanston and Germiston) and KwaZulu-Natal (Pietermaritzburg).

Pest status: No specific details available, but see introductory remarks to family. Considered a threat to endemic, ground-dwelling snails in Hawaii (Severns 1984; Meyer 2005, 2006) and has invaded areas of native vegetation in Tristan da Cunha (Preece 2001).

Similar indigenous species: *Thapsia pinguis* (Krauss, 1848), which occurs in northeastern South Africa, is somewhat similar, but has microscopic spiral sculpture and a narrower umbilicus with distinct spiral threads inside.

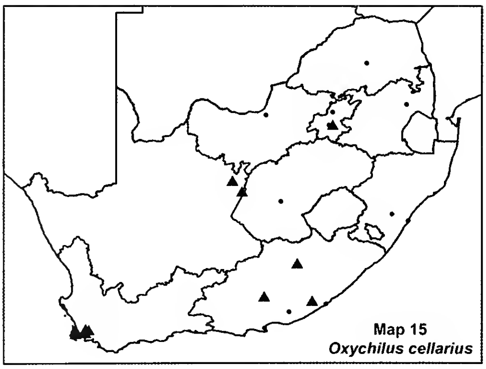
Notes: Although the shell alone offers few distinctive characters other than its smaller size and richer shell colour, the animal is darker than either of the other introduced *Oxychilus* species and the garlic smell which the animal emits when disturbed is characteristic. This originates from the secretions of glandular cells in the mantle edge, close to the pneumostome (Lloyd 1970b). The main volatile component is I-propanethiol, which appears to be linked to sulphur-rich protein within the gland cells. The secretion is emitted as a defensive response when the animal is irritated and is known, at least in the case of hedgehogs, to be an effective deterrent.

Oxychilus cellarius (Müller, 1774)

(cellar glass snail)

Figure 22

FIGURE 22.—*Oxychilus cellarius* (Müller, 1774), Rondebosch, Cape Town, diameter 9.0 mm (NMSA A9774 [1916]).



Helix cellaria Müller 1774: 28; Benson 1850: 217.

Zonitoides cellarius; Gibbons 1878: 367.

Hyalina cellaria; Gibbons 1879: 282.

Hyalina (*Polita*) *cellaria*; Boettger 1910: 455.

Polita cellaria; Connolly 1912: 113; 1916: 182.

Vitrea cellaria; Melvill & Ponsonby 1898: 184.

Oxychilus cellarius; Connolly 1939: 170; Quick 1952: 188; Van Bruggen 1964: 162.

Oxychilus (*Oxychilus*) *cellarius*; Van Bruggen 1980: 227.

Type loc.: '*In cellis vinariis Havniae*' (in wine cellars in Copenhagen).

Description: Resembles *O. draparnaudi*, but smaller (diameter 9–12 mm) and last whorl not as broad. Animal usually pale grey, mantle edge with grey/brown spots.

Habitat: Widely tolerant in its native Europe, living in a range of habitats, including forest, woodland, grassland and accumulations of rock debris, particularly in calcium-rich areas. Also common in suburban habitats such as parks, gardens, ruderal land, cellars and tombs. Lives in loose soil, under mosses, ground-cover vegetation and stones (Rigby 1963; Evans 1972; Kerney 1999). Most South African records are from gardens.

Date of introduction: Prior to 1846.

First SA record: Benson (1850), Rondebosch, Cape Town, W. Cape.

Global distribution: Native to western and central Europe. Introduced also to North America (Robinson 1999; Forsyth 2004), South America (Quick 1952; Stuardo & Vega 1985; Ramírez *et al.* 2003; Simone 2006), Madeira (Seddon 2008), St Helena (Crowley & Pain 1977), Ascension (Ashmole & Ashmole 1997), S.E. Australia (Smith 1992), Tasmania (Kershaw 1991), New Zealand (Barker 1999) and perhaps Hawaii (Cowie 1997).

Distribution in SA (Map 15): Known from W. Cape (Cape Peninsula, Cape Town, Somerset West and Stellenbosch area), E. Cape (Dordrecht, King William's Town and Somerset East), N. Cape (W. Griqualand and Kimberley) and Gauteng (Germiston). Also recorded from Zimbabwe (Bulawayo) (Van Bruggen 1980).

Pest status: No specific details available, but see introductory remarks to family.

Similar indigenous species: See *O. alliarius* above.

Notes: Characterised by the pale shell and pale grey animal with spotted mantle. Biological and anatomical information on the species was given by Rigby (1963). In Britain the duration of the life cycle is around 14 months, with an extended breeding season lasting from January to August, peaking in April–May (Spring).

Oxychilus draparnaudi **(Beck, 1837)**

(Draparnaud's glass snail, dark-bodied glass snail)

Figure 23

Helix (Helicella) draparnaldi Beck 1837 (in 1837–8): 6 [*nom. nov.* for *Helix nitida* (*non* Gmelin, 1791, *nec* Müller, 1774) Draparnaud, 1805 = *nom. nov.* for *H. lucida* (*non* Pultney, 1799] Draparnaud, 1801] [misspelling of *draparnaudi*, IUCN Opinion 336, 1955, *fide* Giusti & Manganelli, 1997].

Polita draparnaudi; Connolly 1912: 114; 1916: 183.

Oxychilus draparnaldi [*sic*]; Connolly 1939: 170.

Oxychilus lucidus; Quick 1952: 188.

Oxychilus draparnaudi; Van Bruggen 1964: 162

Type loc.: France, probably in the Montpellier area (Giusti & Manganelli 1997).

Description: Shell disc-like, consisting of up to 6 flattened whorls; last whorl noticeably wider than previous whorl; smooth and somewhat glossy with faint growth-lines extending from suture; umbilicus moderately wide, not eccentric. Slightly translucent, pale horn-brown, paler and rather milky on base. Diameter up to 16 mm. Body blue-grey, mantle edge dark grey, lacking spots.

Habitat: Found in its native range in sheltered, moist situations, particularly in gardens, greenhouses and ruderal habitats (Kerney 1999). In South Africa most historical records are from suburban areas, but it has now evidently spread into native habitats and is abundant in the leaf litter of the forested slopes of Table Mountain, above the suburbs of Newlands and Kirstenbosch, and probably more widely so on the Cape Peninsula.

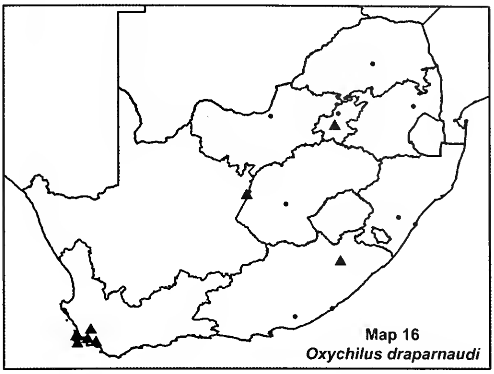
FIGURE 23.—*Oxychilus draparnaudi* (Beck, 1837), Skeleton Gorge, above Kirstenbosch, Cape Town, diameter 10.7 mm (NMSA W1474 [2004]).

Date of introduction: *Circa* 1908 or before (Connolly 1916).

First SA record: Connolly (1912), Rondebosch and Kennilworth, Cape Town, W Cape.

Global distribution: Native to western Europe and the western Mediterranean. Introduced also to North America (Robinson 1999; Forsyth 2004), Bermuda (Bieler & Slapcinsky 2000), Madeira (Seddon 2008), Réunion (Stévanovitch 1994; Griffiths & Florens 2006), Asia (Barker 1999), S.E. Australia (Smith 1992), Tasmania (Kershaw 1991) and New Zealand (Barker 1999).

Distribution in SA (Map 16): Recorded from W. Cape (Cape Town, Cape Peninsula, Houhoek, Paarl and Somerset West), E. Cape (Ugie), N. Cape (Kimberley) and Gauteng (Johannesburg).



Pest status: No specific details available, but see introductory remarks to family.

Similar indigenous species: Similar to species of *Nata* Watson, 1934, particularly *N. vernicosa* (Krauss, 1848), but *O. draparnaudi* is generally more depressed and lacks the distinct axial riblets typical of most *Nata* species.

Notes: The large size, blue-grey body and unspotted mantle are reportedly characteristic. Rigby (1963) noted that in Britain, egg-laying in *O. draparnaudi* occurs in autumn and winter, rather than in spring (cf. *O. cellarius*). Juveniles are most abundant in spring when there is also a die-off of larger specimens.

The relative abundance of this species in natural habitats in the Cape Town area is of potential concern. Its impact on the indigenous snail fauna of such habitats is a topic requiring study (cf. Frest & Rhodes 1982).

Family: Pristilomatidae Cockerell, 1891

A family of small to minute snails possessing whitish to almost transparent, lenticular shells with tightly coiled whorls, frequently smooth and glossy. Poorly known biologically, but some species omnivorous, feeding on decaying plant material and small, soft-bodied invertebrates, including other snails (Barker 1999). Often classified as a subfamily of the Zonitidae. I follow Bank *et al.* (2001), Falkner *et al.* (2001) and Hausdorf (2002) in referring *Hawaiia* and *Vitrea* to the Pristilomatidae. The name Vitreidae Baker, 1930 is a junior synonym.

Hawaiia minuscula (Binney, 1841)

(minute gem)

Figure 24

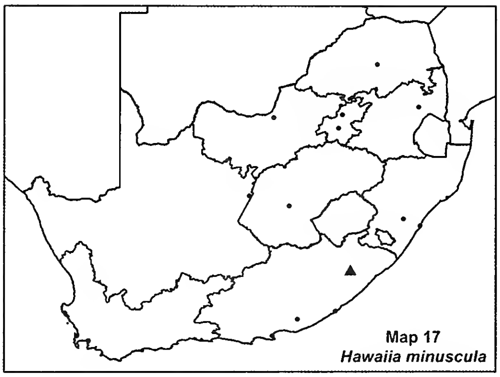
Helix minuscula Binney 1841: 435, pl. 22, fig. 4.

Helix kawaiensis Reeve 1854 in 1851–54: pl. 182, fig. 1256.

Type loc.: Ohio, USA (Pilsbry 1946).

Description: Shell minute, depressed but retaining a low spire; whorls rounded, ± 4–5 in number, relatively tightly coiled and with a strongly impressed suture; sculptured by numerous close-set growth-lines (fine axial riblets), strongest on apical surface, and with microscopic close-set spiral sculpture almost throughout; aperture almost circular except where interrupted in parietal region, outer lip

FIGURE 24.—*Hawaiia minuscula* (Binney, 1841), Langeni Forest Station, Mthatha area, E. Cape, diameter 2.1 mm (NMSA W4026 [2006]).



neither thickened nor flaring; umbilicus wide, the coils of the spire whorls clearly visible inside. Translucent milky white, often with attached organic debris and soil particles. Diameter 2.2–2.5 mm.

Habitat: A common snail in many parts of northern America, with catholic habitat requirements, occurring in wooded and open habitats, as well as parks and gardens. Largely a greenhouse alien in Europe (Kerney *et al.* 1983). The single known locality in South Africa was a neglected garden associated with staff accommodation at a major forestry plantation and sawmill. Its relatively remote location belies the extent of habitat transformation in the area.

Date of introduction: Prior to 2006.

First SA record: Not previously recorded.

Global distribution: Native to North America (Pilsbry 1946) and perhaps parts of Latin America (Hausdorf 2002). Introduced to Jamaica (Rosenberg & Muratov 2006), the Bahamas (Deisler & Abbott 1984), Bermuda (Bieler & Slapcinsky 2000), Madeira (Seddon 2008), northwestern Europe (Kerney & Cameron 1979), Morocco (Seddon 2008); Israel (Roll *et al.* 2009), eastern Asia (Peile 1936), Japan (Kano 1996; Ueshima *et al.* 2000; Sasaki 2008), New Caledonia (Solem 1964), Australia (Smith 1992), Hawaii and other Pacific islands (Preece 1995; Cowie 1997, 2001b).

Distribution in SA (Map 17): Known only from Langeni Forest Station (sawmill village), west of Mthatha, E. Cape.

Pest status: Not known to be pestiferous.

Similar indigenous species: Resembles a number of small *Trachycystis* species, but the combination of small size, whitish colour, rounded whorls, impressed suture and broad umbilicus render *H. minuscula* relatively distinctive.

Notes: The generic name for this species is singularly inappropriate and results from the fact that the type species of *Hawaiia*, *Helix kawaiensis* Reeve, 1854 was described on the basis of *Hawaiia minuscula* populations introduced to Hawaii.

Although the species has been recorded on only one occasion in South Africa, the association of this record with the forestry industry strongly suggests that it is established in one or more sylviculture nurseries from which it may have been more widely dispersed to plantations (see also *Discus rotundatus*).

Vitrea contracta (Westerlund, 1871)

(milky crystal snail, contracted glass snail)

Figure 25

Zonites (Vitrea) crystallina contracta Westerlund 1871: 56.

Type loc.: Sweden: Blekinge, Ronneby.

Description: Shell minute and low-spired, comprising 4.5–5.0 narrowly expanding (tightly coiled) whorls; suture shallow; smooth and glossy, with only ill-defined growth-lines, strongest just below suture; umbilicus relatively narrow and deep, not eccentric; aperture lunate, not thickened inside outer lip when mature. Glossy, transparent to translucent milky white. Diameter up to 2.5 mm.

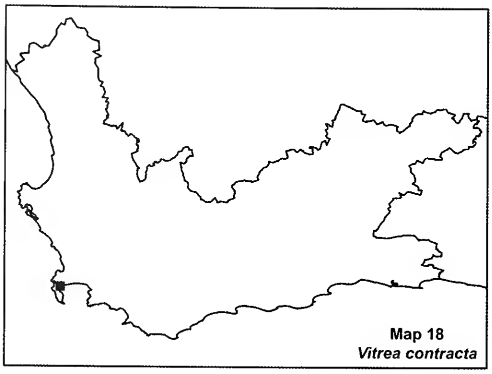
Habitat: Lives in a wide range of habitats including deciduous woodlands, hedgerows, grassland, pasture, cliffs and stone walls in Europe, generally in somewhat drier environments than *V. crystallina*, favours lime-rich soils (Kuiper 1964; Kerney 1999). Known in South Africa only from woodland on the Cape Peninsula.

Date of introduction: Prior to 2004.

First SA record: Not previously recorded, but see notes relating to *V. crystallina*.

Global distribution: Indigenous to much of Europe (north to southern Scandinavia), Ukraine, Turkey, Caucasia and Middle East and North Africa (Riedel 1980). Introduced also to California and Washington (Roth 1977; Roth & Pearce 1984), Canada (Forsyth 2004), Colombia (Hausdorf 2002), Madeira

FIGURE 25.—*Vitrea contracta* (Westerlund, 1871), Skeleton Gorge above Kirstenbosch, Cape Town, diameter 2.5 mm (NMSA W7093 [2008]).



(Seddon 2008) and Australia (Long 1972; Smith 1992).

Distribution in SA (Map 18): Currently recorded only from the east-facing slopes of the Table Mountain massif (Kirstenbosch to Kalk Bay), but almost certainly more widely distributed in the Cape Town area and on the Cape Peninsula.

Pest status: Unlikely to be pestiferous.

Similar indigenous species: None of the minute, discoidal indigenous species have such a smooth, glossy almost transparent shell.

Notes: Although this species has not previously been recorded in South Africa, early workers treated *Vitrea contracta* merely as a variety *V. crystallina*, and prior records of the latter may have included *V. contracta* specimens (see notes under *V. crystallina*). Since some of the material recorded here was obtained in indigenous habitats, it seems likely that it is not a recent introduction.

Vitrea contracta is smaller (diameter < 2.5 mm) and more tightly coiled than *V. crystallina*, has a regular rather than eccentric umbilicus and lacks a thickened subterminal band inside the outer lip (Kuiper 1964). In addition, Valovirta & Väisänen (1986) have shown that the two species can be reliably separated using a discriminant function based on the number of whorls, shell height and breadth of the last whorl. Using these criteria, the material recorded here is clearly referable to *V. contracta*.

Vitrea crystallina (Müller, 1774)

(common crystal snail)

Figure 26

Helix crystallina Müller 1774: 23.

Vitrea crystallina; Melvill & Ponsonby 1898: 184; Connolly 1912: 111; 1916: 182; 1939: 172; Quick 1952: 188; Van Bruggen 1964: 162.

Type loc.: Near Copenhagen, Denmark.

Description: Shell very small and low-spired, comprising 4.5–5.0 narrowly expanding whorls; suture shallow; smooth and glossy, with only ill-defined growth-lines, strongest just below suture; umbilicus relatively narrow and deep, slightly eccentric. Glassy and largely colourless, but interior somewhat thickened just behind aperture lip, producing a diffuse milky white subterminal axial band (mature specimens only). Diameter 3.0–4.0 mm.

Habitat: Lives in a wide range of moist habitats including evergreen and deciduous woodlands, hedgerows, grassland, pasture, road verges and marshes in Europe (Kuiper 1964;

FIGURE 26.—*Vitrea crystallina* (Müller, 1774), diameter 3.3 mm, Oberbayern, Germany, (NMSA G9468).

Kerney 1999), and on a variety of soil types. Known in South Africa only from suburban gardens.

Date of introduction: Prior to 1890. Connolly (1916) noted that R.M. Lightfoot [general scientific assistant at the South African Museum] had first noted the species in the Cape Town area in 1890.

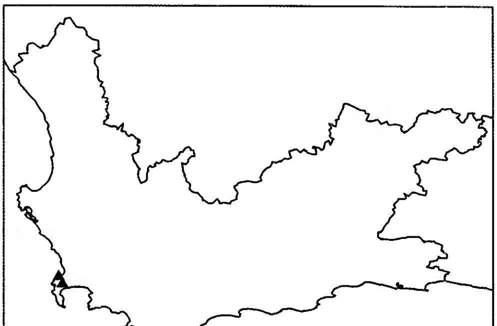
First SA record: Melvill & Ponsonby (1898), Cape Town, W. Cape.

Global distribution: Native to and widespread in Europe. Introduced also to Australia (Cotton 1954), Tasmania (Kershaw 1991) and New Zealand (Barker 1999).

Distribution in SA (Map 19): Recorded only from W. Cape, in the environs of Cape Town [central Cape Town and Wynberg, both early records (Connolly 1916)].

Pest status: Unlikely to be pestiferous.

Similar indigenous species: Some *Trachycystis* species (Charopidae) may be of similar size and shape, but all are to some extent coloured. The colourless glassy appearance of *Vitrea crystallina* renders it distinct from



Map 19
Vitrea crystallina

these. The introduced *Zonitoides arboreus* (below) is larger, has stronger growth-lines and is of a yellowish brown colour.

Notes: Despite that Connolly (1939) indicated the species to be plentiful in Cape Town and its suburbs, there remain few records, no doubt because of its small size. In the early literature, the smaller but similar *Vitrea contracta* (see above) was considered to be a variety of *V. crystallina* and the identity of the original material recorded by Connolly needs to be confirmed, if it can be traced (none is present in the Natal Museum or South African Museum). Preece (2001) recorded *V. contracta* from Tristan da Cunha in the South Atlantic and observed that, since much of the alien Palaearctic flora and fauna of this island is thought to have arrived there via South Africa, it was surprising that *V. contracta* had not been recorded in South Africa. All the remaining alien terrestrial molluscs recorded from Tristan da Cunha are also known as aliens in South Africa. His suggestion that South African material recorded as *V. crystallina* may have represented an aggregate including *V. contracta* seems likely, particularly since the latter has now been found here. It is also possible that Connolly's material included only *V. contracta* and the occurrence of *V. crystallina* in South Africa requires confirmation.

Family: Bradybaenidae Pilsbry, 1934

A family of moderately sized, herbivorous snails with both arboreal and terrestrial species; shell smooth or strongly sculptured, many boldly coloured. The family is most diverse in eastern Asia, particularly in the Philippines where some of the larger more spectacular species are to be found. One of the smaller species, *Bradybaena similaris*, has become a noted world-traveller.

Bradybaena similaris (Férussac, 1822)

(Asian tramp snail)

Figure 27

Helix similaris Férussac 1821 in 1821–22: 47 [*nomen nudum*], Timor.

Helix similaris Férussac 1822 in 1821–22: ii, pl. 25B, fig. 1, 4 [see Bank & Menkhorst (2008) for discussion of authorship and date of publication].

Helix similaris; Férussac in Rang 1831: 15, Bourbon [Réunion]......etc.

Eulota similaris; Melvill & Ponsonby 1898: 184; Connolly 1912: 156; 1916: 185.

Bradybaena similaris; Connolly 1939: 271; Barnard 1951: 148; Van Bruggen 1964: 162; Herbert & Kilburn 2004: 276.

Type loc.: Cited as Timor by Férussac (1821), but latter given as Réunion by Rang (1831).

Description: Shell roundly conical, wider than high, spire relatively low; whorls 5.0–6.0, last adult whorl deep, slightly angled at periphery; suture level with peripheral angulation; base rounded, umbilicus open; surface silky, sculptured with microscopic growth-lines in the form of weak, close-set axial riblets, and with even finer spiral threads; lip of aperture flaring outwards, strongly so at columella, partly obscuring umbilicus. Evidently polymorphic in colour with red-brown and yellowish white forms; all specimens seen from South Africa have been translucent white with a pale buff or straw-coloured periostracum and sometimes with a brown spiral line at the periphery; flared lip of aperture white. Diameter up to 15 mm.

Habitat: Little specific data available for South African specimens, but has been found in municipal nurseries. Benthem Jutting (1950) reported it occurring under stones, amongst grass sods and low shrubs, and sometimes on tree trunks in Indonesia. Evidently favours gardens, greenhouses and wasteland in regions to which it has been introduced.

Date of introduction: Prior to 1858. Connolly (1916) reported that the botanist R.W. Plant had collected the species in Durban, around 1860. Since Plant died in 1858 (Gunn & Codd 1981), it must be assumed that the introduction pre-dated this.

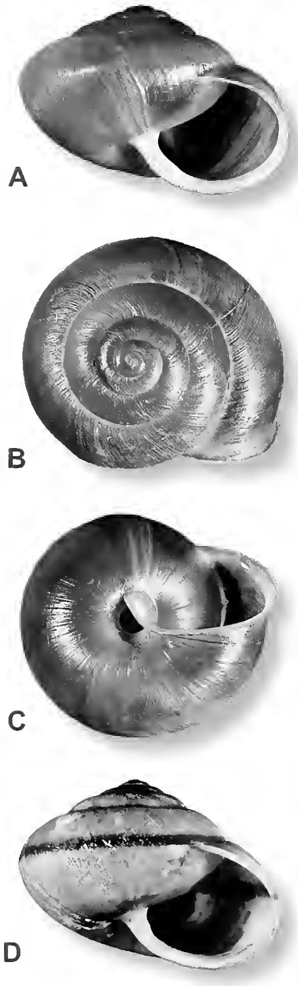
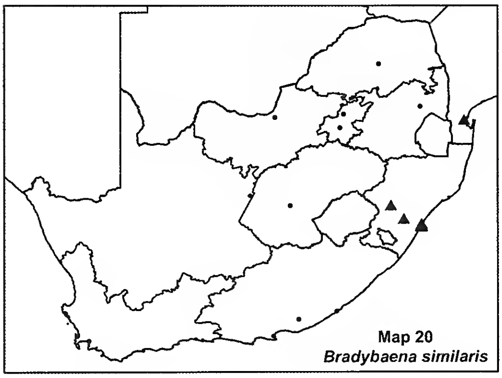


FIGURE 27.—*Bradybaena similaris* (Férussac, 1822). A–C, Rodrigues Is., diameter 12.6 mm (NMSA F4835 [± 1920]); D, Bridgevale, Parks Dept nursery, Durban North, diameter 14.2 mm (NMSA V9234 [2001]).

First SA record: Melvill & Ponsonby (1898), locality given as 'Natal' (probably first introduced in Durban).

Global distribution: Native to eastern Asia, southern China to Indonesia. Now almost pantropical, occurring in the southeastern states of the USA (Hubricht 1960; Dundee 1970), the Caribbean (Chase & Robinson 2001; Rosenberg & Muratov 2006), Bermuda (Bieler & Slapcinsky 2000), Latin America (Smith 1989; Robinson 1999; Scarabino 2003), Ascension (Ashmole & Ashmole 1997), Madagascar (Fischer-Piette *et al.* 1975), Mascarene Islands (Stévanovitch 1994; Griffiths 1994;Griffiths & Florens, 2006), Comoros (Fischer-Piette & Vukadinovic 1974), Seychelles (Gerlach 2006), Sri Lanka (Mordan *et*



al. 2003), Japan (Ueshima *et al.* 2000), New Caledonia (Solem 1964), Australia (Smith 1992; Stanisic 1998a), Hawaii (Cowie 1997), Samoa (Cowie 1998b) and many islands in the Pacific Ocean (Benthem Jutting 1950; Cowie 2000).

Distribution in SA (Map 20): Recorded in South Africa only from KwaZulu-Natal (Durban, Pietermaritzburg and Estcourt—all localities on the main Durban–Johannesburg road), but known also from Maputo in Mozambique (specimens in NMSA collection).

Pest status: Reportedly pestiferous, *inter alia*, on ornamental flowers, brassicas, cucurbits, legumes, grapevines, mango, papaya, banana, coffee and citrus (Dundee & Cancienne 1978; Stanisic 1998a; Chang 2002; Garcia 2004). May occur at high population densities, causing problems in clean harvesting of crops.

Similar indigenous species: Resembles some of the larger *Trachycystis* species (pinwheel snails) occurring in KwaZulu-Natal, e.g. *T. loveni* (Krauss, 1848), but these generally have a lower spire, a stronger peripheral angulation, a narrower umbilicus and usually have periostracal hairs when alive.

Notes: The species was collected in 'Stella Bush', an indigenous coastal lowland forest habitat on the Durban 'Berea', in the first half of the 20th century by H.W. Bell-Marley, suggesting that it had to some extent invaded natural habitats. However, there have been few records of the species in KwaZulu-Natal during the last 50 years, suggesting that it has not spread widely. Nonetheless, specimens have recently (2001) been found in the nursery of the Durban Parks Department at Bridgevale, Durban North, indicating that the species is still extant in the region. Further information on the biology, life cycle, population genetics and control of *B. similaris* was provided by Komai & Emura (1955), Dundee (1970), Chang (2002) and Carvalho *et al.* (2008).

Family: Cochlicellidae Schileyko, 1972

A family of relatively small, herbivorous snails with an elongate shell; native to western Europe and the Mediterranean; catholic in habitat preferences and tolerant of disturbance; frequently synanthropic and proficient travellers that have been dispersed widely around the globe, particularly to areas with a Mediterranean climate.

The genus *Cochlicella* has traditionally been referred to either the Helicidae (Zilch 1959–60; Kerney *et al.* 1983) or more recently the Hygromiidae (Nordsieck 1987; Vaught 1989; Faulkner *et al.* 2001; Anderson 2005), but morphological and molecular evidence suggest that the genus is somewhat distinct from other clades within the Hygromiidae (Schileyko & Menkhorst 1997; Steinke *et al.* 2004; Manganelli *et al.* 2005) and the Cochlicellidae is now recognised as a separate family level entity (Bouchet & Rocroi 2005). In addition, *Cochlicella barbara* appears to differ morphologically from *Cochlicella s.s.* and was referred to a new genus *Prietocella* by Schileyko & Menkhorst (1997). However, I follow recent European authors in treating this as a subgenus of *Cochlicella* (Faulkner *et al.* 2001; Anderson 2005).

Cochlicella barbara (Linnaeus, 1758)

(pot-bellied snail, banded conical snail, small conical snail, small pointed snail, tower snail)

Figure 28

Helix barbara Linnaeus 1758: 773.

Cochlicella acuta (*non* Müller, 1774); Connolly 1912: 157; 1916: 186; Quick 1952: 188.

Cochlicella ventricosa; Connolly 1939: 270; Barnard 1951: 148, pl. B, fig. 6; Van Bruggen 1964: 162; Els 1973.

Prietocella barbara; Schileyko & Menkhorst 1997.

Type loc.: Algeria.

Description: Shell small, elongate-conical with 7–8 convex whorls; surface dull, smooth except for some irregular axial riblets just beneath suture; umbilicus open, narrow and partially concealed by reflected inner lip of aperture. Coloration variable, ranging from an almost uniform dirty white to pale trans-

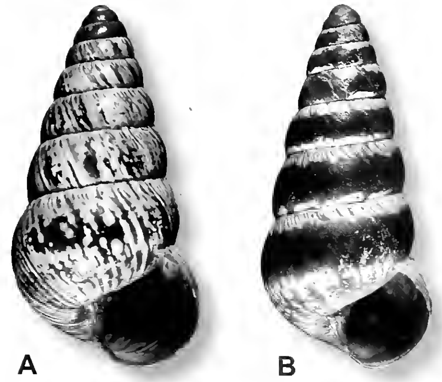
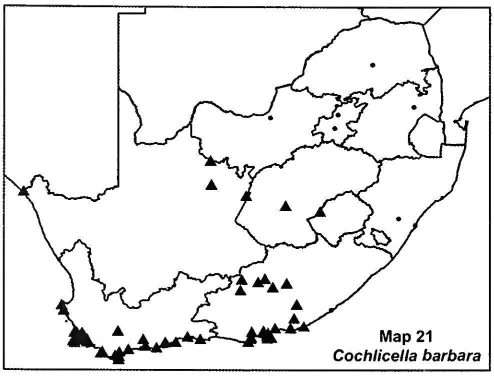


FIGURE 28.—*Cochlicella barbara* (Linnaeus, 1758), Wilderness, W. Cape. A, mottled specimen, length 11.1 mm (NMSA V4390 [1997]); B, banded specimen, length 11.4 mm (NMSA 4076 [1963]).



lucent buff mottled with white and brown blotches and flecks; also frequently with a broad, darker brown spiral band at mid-whorl. Adult length 8–12 mm.

Habitat: Favours areas with a relatively dry, Mediterranean climate, especially near the coast. Common in gardens, cultivated and waste land where it may occur in large numbers under favourable conditions. May thrive, largely unseen, beneath the surface of lawns.

Date of introduction: Prior to 1909 (Connolly 1916).

First SA record: Connolly (1912, as *Cochlicella acuta*), under spare railway sleepers, St James Station, Cape Peninsula, W. Cape (Connolly 1916).

Global distribution: Native to the Mediterranean. Introduced also to several European countries north of the Mediterranean (Kerney 1999), the USA [California and South Carolina] (Pilsbry 1939; Roth & Hertz 1997), Bermuda (Bieler & Slapcinsky 2000), Madeira (Seddon 2008), Israel (Roll *et al.* 2009), Japan (Roth & Hertz 1997), Australia (Pomeroy & Laws 1967; Smith & Kershaw 1979; Baker 1986; Eddie 1997), Tasmania (Kershaw 1991) and New Zealand (Barker 1999).

Distribution in SA (Map 21): Known from numerous coastal localities along the Cape south coast, from the environs of False Bay to Port Alfred. Also recorded from isolated localities on the Atlantic coast as far north as the South Africa/Namibia border (Alexander Bay) and from scattered inland localities in N. Cape (Kimberly, Kuruman and Lime Acres), Free State (Bloemfontein), E. Cape (Cradock, Fort Beaufort, Graaff-Reinet, Grahamstown and Tarkastad) and Lesotho (Maseru). There is also an unlocalised record of the species from the 'Natal South Coast' (Van Bruggen 1964), but the species is not currently known from KwaZulu-Natal.

Pest status: *Cochlicella barbara* is herbivorous and, despite being small, may cause appreciable agricultural/horticultural damage when population densities are high. Barker (1999) recorded densities of over 1 000 snails/m^2 in pasture in New Zealand and damage to legume-based pasture has been reported in south-eastern Australia (Baker 1986). Evidently a pest of wheat and canola in the Bredasdorp area, W. Cape. Reported to act as an intermediate host for protostrongylid nematode worms, e.g. the sheep lung worm *Protostrongylus rufescens* (Kershaw 1991; Morrondo-Pelayo *et al.* 1992). Unlike *Cochlicella acuta* (see potential future introductions below), *C. barbara* is more cryptic in its habits and does not climb vegetation to aestivate.

Scientists at the South Australia Research and Development Institute, Adelaide, have assessed a number of Mediterranean sciomyzid and sarcophagid flies as potential biocontrol agents for both *Cochlicella barbara* and *C. acuta* (Coupland 1996), and *Sarcophaga penicillata* has subsequently been released in the hope of controlling *C. acuta* (Baker & Charwat 2000; Kempster & Charwat 2003, Leyson *et al.* 2003).

Similar indigenous species: None.

Notes: This is an opportunistic species easily translocated with plants, building materials and household goods, and it could therefore crop up wherever there is human habitation. However, whether material translocated to subtropical localities would survive in the long-term is doubtful. The lack of records

from the Durban area suggests that the warm, summer rainfall climate that prevails along the eastern seaboard is not favourable for this species.

Boulange (1961) investigated the reproductive biology of the species in northern France and showed that there the species lives for approximately one year, and that mating commences in spring and egg-laying continues through summer and autumn, with hatching occurring in autumn and early winter, and again in late winter of the following year. However, since the reproductive strategies of many successful alien snails can be varied, it does not follow that the same regimen will occur under South Africa conditions. Indeed, the related species, *C. acuta* is an annual, with a summer–autumn breeding season in Europe, but may be biennial with an autumn–spring breeding season in certain agricultural conditions in South Australia (Baker *et al.* 1991; Baker & Hawke 1991).

There has been some confusion concerning the identification and correct name for this species in South Africa. Connolly (1912) originally recorded South African material as *Cochlicella acuta* (Müller, 1774), but later (Connolly 1939), realising that *C. acuta* represented a distinct species, he changed this identification to *C. ventricosa* (Draparnaud, 1801). This in turn is now considered a junior synonym of *C. barbara*. The true *C. acuta*, which has a longer, more elongate shell with more whorls and a sharper apex, is not currently known to occur in South Africa, but it is quite possible that it could be introduced here in the future (see potential future introductions below).

Family: Helicidae Rafinesque, 1815

A very large and diverse family containing some of the most invasive of snails and some of the most serious pests. Originating in Europe, western Asia and North Africa, representatives of the family are now widely distributed around the globe. Many are polyphagous herbivores, eating living green plant material, and thrive in gardens, ruderal habitats, orchards, vineyards and croplands. Four species are known from South Africa, all alien.

Eobania vermiculata (Müller, 1774)

(vermiculate snail, chocolate-band snail, nudelschnecke, mourguette de Provence, vinyala)

Figure 29

Helix vermiculata Müller 1774: 20.

Eobania vermiculata; Sirgel 1990; Sacchi 1996: 125; Herbert & Sirgel 2001; Sirgel in Zimmermann 2003: 53.

Type loc.: '*In Italiae sabulosis juxta torrentes*'.

Description: Shell of moderate size, rather low-spired (compared with *Cornu aspersum*); approximately five whorls, last adult whorl evenly rounded, suture line dropping strongly just prior to outer lip and aperture set an oblique angle; aperture lip strongly flaring and noticeably thickened at base of inner lip; umbilicus lacking, umbilical region covered with pale callus deposit extending from lower part of inner lip. Colour pattern variable, ground colour generally pale, some specimens strongly marked with bold chocolate-brown spiral bands with paler intervals, others almost uniformly pale brown (some intermediate), most with numerous, fine, whitish, worm-like (vermiculate) markings, although these are scarcely evident in some strongly marked specimens; basal callus and flaring edge of outer lip white (cf. *Otala punctata*). Diameter 22–33 mm.

Habitat: Recorded in its native Europe from fields, hedges, gardens and vineyards, often in sheltering localities, such as under windowsills, in crevices in stone walls, behind shrubs and amongst low-growing vegetation (Kerney & Cameron 1979; Nicòtina & Solazzo 1990). Reported from gardens, parks and cemeteries in Australia (Smith & Kershaw 1979; Shea 1992). In the Port Elizabeth area it is locally abundant in cemeteries, parks, suburban gardens, ruderal habitats and coastal scrub, and it has also been found in horticultural nurseries and garden centres.

Date of introduction: Prior to 1987 (Herbert & Sirgel 2001).

First SA record: Although Sirgel (1990) mentioned the occurrence of *Eobania vermiculata* in South Africa, this was in an unpublished report. The first published record was that of Sacchi (1996), Port Elizabeth, E. Cape.

Global distribution: Native to the Mediterranean, from North Africa through Spain,

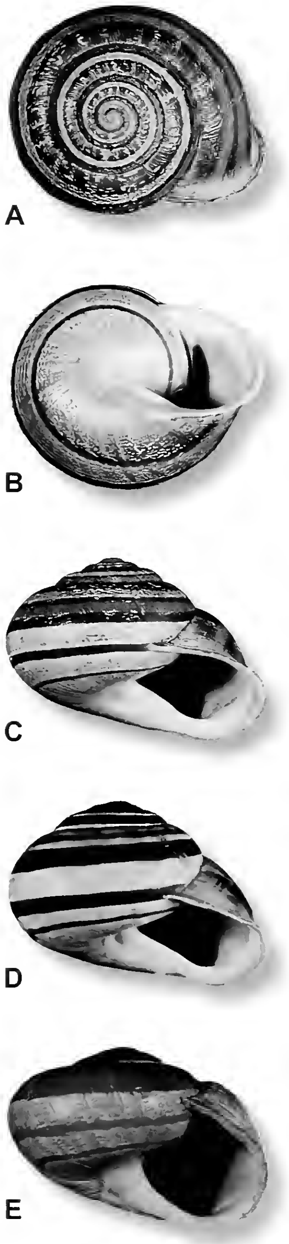
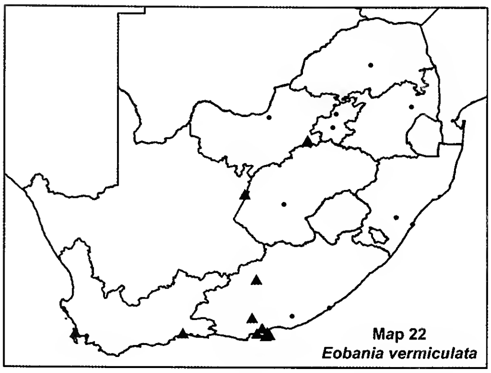


FIGURE 29.—*Eobania vermiculata* (Müller, 1774). A–C, Port Elizabeth, diameter 29.5 mm (NMSA V8360 [1987]); D, Vredehoek, Cape Town, diameter 27.3 mm (NMSA V8263 [2000]); E, Kimberley, diameter 21.4 mm (NMSA V8200 [2000]).

Italy and east to Greece and Turkey (Kerney 1976; Schütt 2001). Introduced also to several states in the southern USA (USDA 1999; Roth & Sadeghian 2003), Britain (Norris 2006; Notton 2006), Japan (Ueshima *et al.* 2004) and Australia (Petterd & Hedley 1909; Cotton 1954; Smith & Kershaw 1979,



but now extinct there; Shea 1992). It has also expanded its Mediterranean range into Israel (Mienis 1973; Roll *et al.* 2009) and beyond into the Middle East and southwestern Asia (Crimea and Turkmenistan) (Medynskaya & Popov 1998; Izzatullaev 1996).

Distribution in SA (Map 22): Principally known from E. Cape where its main focus is in Port Elizabeth, the site of introduction, but with human assistance, it is spreading outwards from this nucleus into neighbouring areas (Uitenhage, Van Staden's River mouth, Loerie and Cradock). An established colony also exists in Cape Town, probably as a result of a separate introduction in the 1990s. Further isolated records from George, N. Cape (Kimberley) and North West Province (Potchefstroom).

Pest status: Unclear, but since the species is a large polyphagous herbivore feeding on living plant material, it has the potential to become problematic. Certainly, in suburban gardens in the Humewood, Summerstrand and Walmer suburbs of Port Elizabeth it is abundant and pestiferous. As yet there is no information to indicate whether, like *Cornu aspersum,* it will largely be restricted to transformed habitats or whether, like *Theba pisana,* it will spread into relatively pristine natural ones such as coastal fynbos (Macdonald & Jarman 1984).

The species is easily translocated and is the second most frequently intercepted non-native mollusc amongst goods imported to the USA, accounting for over 5% of all molluscan interceptions (Robinson 1999), only marginally less often than *Cornu aspersum*. Contaminated goods include a variety of imported fruit, vegetables, cut flowers and horticultural plants (USDA 1999; Norris 2006). As the species spreads in South Africa, contamination of export produce could present a problem. It has been identified as a pest of olives and cit-

rus in Turkey, potentially causing a decrease in photosynthetic capacity through leaf consumption (Bozbuga & Elekcioglu 2008).

Similar indigenous species: None, but see *Otala punctata* below.

Notes: The introduction of this species to South Africa has been discussed in detail by Herbert & Sirgel (2001). It now appears to be well established in the Port Elizabeth–Uitenhage region and its occurrence in garden centres there suggests that it will continue to spread to new areas. Although a variable species in terms of coloration, E. Cape material has a relatively constant colour pattern of bold spiral bands with paler intervals. Cape Town material is more variably marked, but when banded, the dark line immediately above the suture on the spire whorls is uniformly brown, whereas in E. Cape specimens this band is compound, comprising a paler mid-region sandwiched between two thinner dark lines. These phenotypic differences almost certainly reflect genetic differences, indicating that these stocks originated from two separate introductions. Specimens from inland localities, Kimberley and Potchefstroom, are smaller than usual (diameter ± 20 mm), but have a thickened lip indicating maturity. They have the appearance of being stunted and slightly deformed, but otherwise they are typical of less strongly marked specimens of *E. vermiculata*.

Under natural conditions in Greece (where it is native and commercially exploited for food) individuals live for approximately two years, reaching sexual maturity about 20 months after hatching, coincident with the closure of the umbilicus and reflexure of the outer lip. Mating occurs after the first autumn rains, at around age 23 months, followed some 20 days later by egg-laying, most individuals dying within two months thereafter (Lazaridou-Dimitriadou & Kattoulas 1986, 1991, Medynskaya & Popov 1998). Exceptional individuals may live for 3–4 years, reproducing each autumn, although the number of eggs laid decreases each year. Growth is most rapid in the spring and slowest during hibernation and aestivation (Lazaridou-Dimitriadou & Kattoulas 1986, 1991). Beyond age 24 months growth is minimal. *E. vermiculata*, however, it is evidently an adaptable species, able to vary its pattern of reproduction and the length of its dormant periods to suit a range of climatic conditions (Medynskaya & Popov 1998).

Port Elizabeth specimens were first discovered in a cemetery and it is tempting to speculate that the species was introduced in shipments of Italian quarry products imported for the monumental masonry industry (cf. Tang 2004). It has been found in the grounds of a monumental masonry business in the Bakens Valley.

Cornu aspersum (Müller, 1774)

(brown garden snail, common garden snail, bruinslak, escargot petit gris, la zigrinata)

Figure 30

Helix aspersa Müller 1774: 59; Gibbons 1878: 367, 1879: 282; Kew 1893: 204; Melvill & Ponsonby 1898: 184; Fuller 1906: 446; Connolly 1912: 160; 1916: 187; 1939: 266; Gunn 1924; Barnard 1948: vii; 1951: 145, pl. 22, fig. 3; Joubert & Walters 1951; Quick 1952: 183; Van Bruggen 1964: 162, 1970: 469; Swart *et al.* 1976: 190; Bedford 1978: 22; Herbert & Kilburn 2004: 275.

Helix (*Helicogena*) *aspersa*; Boettger 1910: 456.

Type loc.: '*In Italia*'.

Description: Shell of moderate size, globose, comprising 4.5–5.0 evenly rounded whorls; height and diameter ± equal; surface sculptured with fine growth-lines and wrinkled by fine irregular superficial reticulations; suture line dropping noticeably just prior to outer lip and aperture set an oblique angle; aperture subcircular and large, its lip strongly flaring in adults (not so in juveniles); umbilicus lacking, umbilical region covered with whitish callus deposit extending from inner lip. Colour pattern variable, generally mottled brown with up to five broad spiral bands in darker brown, some specimens more uniformly brown or yellowish brown (var. *luteola* Bourguignat, 1864); flaring edge of outer lip white. Diameter 25–40 mm.

Habitat: Largely synanthropic in South Africa, occurring in a wide variety of transformed habitats, particularly in domestic gardens, sheltering amongst vegetation and in shaded positions, often climbing walls. It does not appear to have spread widely into natural habitats, although it may sometimes occur in coastal scrubland/fynbos adjacent to human habitation.

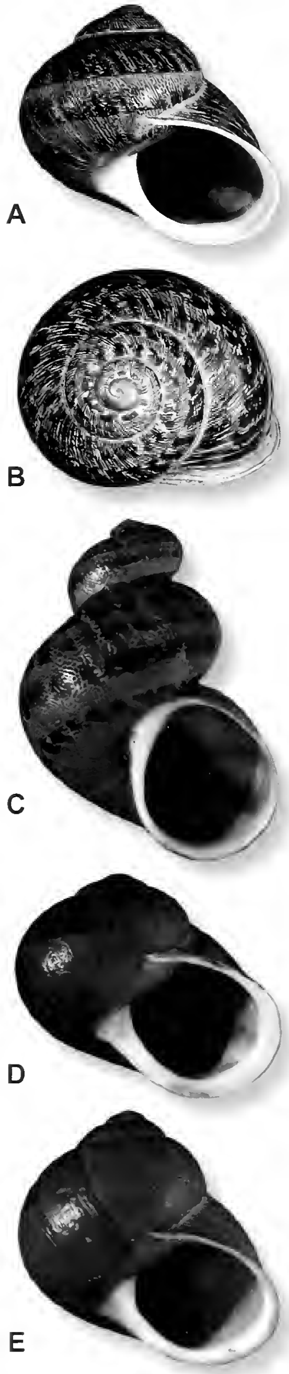
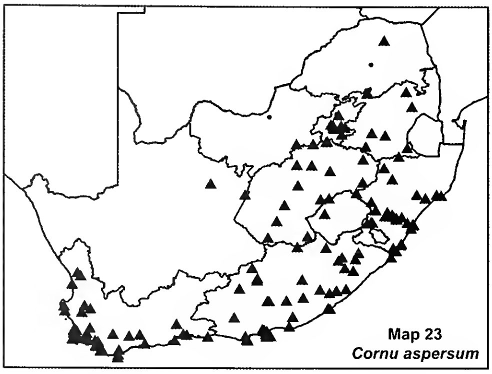


FIGURE 30.—*Cornu aspersum* (Müller, 1774). A, B, strongly patterned specimen, Gansbaai, W. Cape, diameter = 30.4 mm (NMSA V7779 [2000]); C, scalariform freak, Lakeside, Muizenburg, Cape Town area, diameter = 26.0 mm (NMSA V7391 [1999]); D, weakly patterned specimen, with low spire, Langeni Forest Station, E. Cape, diameter = 30.5 mm (NMSA W4023 [2006]); E, uniform brown specimen with elevated spire, Pietermaritzburg, KwaZulu-Natal, diameter = 30.3 mm (NMSA W3462 [2005]).



Date of introduction: 1855. The story of the introduction of this species into South Africa is confused, various authors supplying different versions. It seems, however, that the main culprit was (not surprisingly) a Frenchman, a Mons. Dastre who obtained (either by purchase or as a gift) half a cask of live snails from the captain of a French war-ship docked in Cape Town. He evidently ate the full-grown ones and scattered the juveniles around on his walks in the Cape Town area. The most commonly cited date for this introduction is 1870 (Connolly 1912, 1916, Quick 1952), but Kew (1893), quoting a letter from Edgar L. Layard (Director of the South African Museum and once blamed for the introduction), stated that the event took place in approximately 1855. Similarly, whether Mons. Dastre was a priest or the French Consul, or both, is uncertain. In any event, by 1878, *C. aspersum* was clearly well established, leading Gibbons (1878) to remark that he had never seen it 'so abundant as near Cape Town'.

First SA record: Gibbons (1878), Cape Town, W. Cape.

Global distribution: Native to western Europe and the Mediterranean. Introduced also to North, Central and South America, (Pilsbry 1939; Gammon 1943; Quick 1952; Hanna 1966; Mead 1971a; Stuardo & Vega 1985; Davis 1993; Hausdorf 2002; Scarabino 2003; Forsyth 2004), West Africa (Van Bruggen 1987a), Asia (Davis 1993), Australia and Tasmania (Kershaw 1991; Smith 1992), New Zealand (Barker 1999) and many islands in the Atlantic (Backhuys 1975; Crowley & Pain 1977; Ashmole & Ashmole 2000; Seddon 2008), Caribbean (Davis 1993) and Indo-West Pacific (Solem 1964; Stévanovitch 1994; Cowie 1997, 2000, 2001b; Bokyo & Cordeiro 2001; Griffiths & Florens 2006).

Distribution in SA (Map 23): Widely distributed, occurring in all nine provinces; known from all major urban areas and has also been found around human habitation in many remote rural areas; from sea level to 2 200 m. Also recorded from Lesotho and Zimbabwe (Van Bruggen 1981).

Pest status: This is undoubtedly the most widespread alien snail in South Africa. Its pest status in the region is widely acknowledged, with damage being reported for a range of important commercial crops (including: flowers and ornamentals, field crops, vegetables, deciduous fruit, grapes, berries, citrus and subtropical fruit (Swart *et al.* 1976; Myburgh 1986–90; Schwartz 1988; Ferreira & Venter 1996; Joubert & Du Toit 1998), as well as in domestic gardens (Gunn 1924 and 'Snailiens' project). To date this damage has not been quantified economically in South Africa—an exercise that would be well worth conducting. The abundance of the species appears to be variable, but in favourable years the impact of its depredations may be considerable. Known to act as a vector of plant pathogens such as canker fungi and downy mildew (*Phytophthora* spp.) (Wester *et al.* 1964; El-Hamalawi & Menge 1996; Alvarez *et al.* 2009), which may have implications for the local citrus and avocado industries. May serve as an intermediate host for dicrocoeliid and *Brachylaima* trematode parasites of vertebrates (Spratt 2005; Gürelli & Göçmen 2007).

Similar indigenous species: None.

Notes: Size and coloration of the shell is very variable and several characteristic growth aberrations are known (Chevallier 1977), the two best known being form *scalaris* in which the whorls are scarcely in contact with one another, and form *cornucopiae*, in which the shell is a weakly coiled tube with the whorls widely disjunct. Although rare, both forms have been found in the Cape Town area. Similar freak specimens are known in *Bradybaena fruticum* and *Cepaea nemoralis*, and are thought to result from embryological abnormalities brought on by unfavourable living conditions (Godan 1999).

This species has long been known as *Helix aspersa*, but in recent years specialists have referred it to a variety of other genera, no doubt causing considerable confusion in the process. The issue can be summarised as follows: the type species of the genus *Helix* Linnaeus, 1758, is *H. pomatia* Linnaeus, 1758, but on anatomical grounds this is now considered to be generically distinct from *'Helix' aspersa* (Giusti *et al.* 1995; Manganelli *et al.* 2005). It seems that the oldest appropriate generic name for the species is *Cornu* Born, 1778, of which it is the type species by monotypy. This name has been rejected by some authors on the grounds that it is based on a monstrosity (the *conucopiae* abnormality of *aspersa*) and must be excluded (Barker 1999). However, such names are only to be ignored for the purposes of zoological nomenclature when the name was proposed for teratological material **as such** (ICZN 1999, Art. 1.3.2.). Since this was not the case for *Cornu* (Born was evidently not aware that he was dealing with an abnormal specimen), rejection of the name is not supported and in recent years European workers have begun to use *Cornu* more widely. This is the genus to which the species is referred in the Checklist of European Continental Mollusca (Falkner *et al.* 2001). Those authors who have rejected *Cornu* have variously used the names *Cantareus* Risso, 1826, (e.g. Barker 1999) and *Cryptomphalus* Charpentier, 1837 (e.g. Cossignani & Cossignani 1995), but these are pre-dated by *Cornu*.

A detailed discussion of the biology of this well-known species is not appropriate here. Information can be found in a wide range of sources from biology text books to research literature and pest control manuals. The species is also a major focus for the snail-farming industry and much information is available in the associated heliciculture literature and farming manuals. A useful summary was provided by Barker (1999). Additional information is also readily available on the Internet.

Otala punctata (Müller, 1774)

(white-lipped milk snail, otala de Catalonge, vaqueta)

Figure 31

Helix puncata Müller 1774: 21.

Otala punctata; Herbert & Sirgel 2001.

Otala lactea (*non* Müller, 1774); Walters *et al.* 1990: 83.

Type loc.: '*In Italia*'.

Description: Resembles *Eobania vermiculata* in overall shape (see above), but larger, more flattened and with a different coloration. General pattern of dark and light, brownish,

FIGURE 31.—*Otala punctata* (Müller, 1774), Cape Town, Tygerberg, diameter 34.5 mm (NMSA E2180 [1986]).

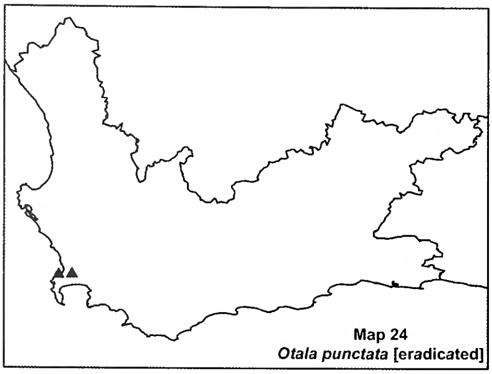
spiral bands overlain with numerous tiny white spots, rather like snowflakes; spire whorls with a dark grey-brown band above suture; interior of aperture, particularly that underlying previous whorl, covered with a dark brown to almost black glaze, which obscures underlying colour pattern; flaring rim of outer lip pale. Diameter up to 40 mm.

Habitat: Known from wasteland, pasture, gardens, vineyards, stone walls and rocky slopes in its native region (Kerney *et al.* 1983). South African material was found in the Cape Town docks and a ruderal habitat in industrial land.

Date of introduction: Prior to 1986.

First SA record: Herbert & Sirgel (2001), Cape Town, W. Cape.

Global distribution: Native to the Iberian Peninsula, southern France and the Maghreb region of North Africa. Introduced also to the USA (USDA 1999), Argentina, Brazil and Uruguay (Mienis 1999a and pers. comm.).



The very similar species *Otala lactea* (Müller, 1774) has been reported from Central America (Smith 1989), Cuba, Bermuda, Canary Islands (USDA 1999; Bieler & Slapcinsky 2000), Madeira and the Azores (Backhuys 1975), and SE Australia (Smith 1992), but some of these records may in fact represent *O. punctata* (see notes below).

Distribution in SA (Map 24): Reliably recorded only from the Cape Town area, but now eradicated there.

Pest status: *Otala punctata* and *O. lactea* are sympatric in parts of their native ranges and are thought to exhibit similar life history patterns (USDA 1999). They may therefore have similar capacity for colonising new territory and be of equal pest risk. Although Smith (1989) considered *O. lactea* only marginally pestiferous, Gammon (1943) believed it to have the potential to become as invasive and problematic as *Cornu aspersum*, if not more so. Mead (1971a) described it as an established garden and horticultural pest in the western and southern United States. Likewise in Bermuda, where it was introduced as a food item, it has escaped and become a serious pest of vegetable and flower crops (Simmonds & Hughes 1963), and it is now one of the most commonly encountered snails on the island (Bieler & Slapcinsky 2000). *O. punctata* is considered a garden pest in Uruguay (Mienis 1999a) and all interceptions of the species entering the USA are considered actionable (USDA 1999), its overall pest risk rating being categorised as high. Anomalously, *O. lactea*, which has been exploited historically as a food source in Europe, can today still be imported alive, under permit, into the USA for human consumption (USDA 1999).

Since the climate of much of the Cape south and west coasts is similar to that of the western Mediterranean (winter rainfall and hot

dry summer), conditions in this part of South Africa might prove highly favourable for both *O. punctata* and *O. lactea*. The prompt initiation of the eradication programme by authorities in the Department of Agriculture was thus an insightful response to its discovery in Cape Town in 1986 (see notes below). The cost of the campaign represents a minor investment compared to the potential long-term costs, had the colony been allowed to spread.

On account of their value as a food item (Mead 1971a), quarantine officials should be aware of the possibility of deliberate as well as accidental introduction of both species.

Similar indigenous species: None.

Notes: In December 1986 a thriving colony of *O. punctata* was discovered in the Tygervallei suburb of Cape Town. The Chief Directorate of the Department of Agriculture and Water Supply (Winter Rainfall Region) was informed of the discovery and a thorough eradication programme was promptly initiated. This population, containing more than 20 000 snails, together with another colony found subsequently in Cape Town docks, was eliminated soon after. No live *O. punctata* have been found at either of these sites since 1988. The cost of the programme was estimated to be R215 000, spread over three years, 1987–1989 (US$1.00 = SAR2.40 at end 1988). Further details of the eradication campaign were provided by Herbert & Sirgel (2001).

O. punctata is frequently confused with *O. lactea* and Mienis (1999a, b) has cautioned that many records of *O. lactea* may in reality represent misidentified *O. punctata* (see also USDA 1999), particularly those from South America (Mienis 2001). Although some authors consider these two nominal taxa to be nothing more than variants of one polymorphic species (Albuquerque de Matos 1989), others believe that there are well-defined shell characters by which they can be consistently separated (Mienis 1999a, b). The latter opinion seems to be the more widespread (Kerney *et al.* 1983; Abbott 1989; Robinson 1999; USDA 1999). Since the Cape Town material has the characteristic snowflake spotting, dark line above the suture and pale margin to the outer lip, Herbert & Sirgel (2001) referred it to *O. punctata*.

Melvill & Ponsonby (1898) recorded *O. lactea* from 'Pondoland', but the specimens are no longer extant and their true identity cannot be confirmed. According to Connolly (1916 [as *Helix faux-nigra*], 1939) the specimens were not in fact collected in Pondoland, but were found alive by a Mrs Barber in 1897, in a garden in Port Alfred. In any event, a self-sustaining population was not established.

Otala lactea has been studied more extensively than *O. punctata*, but neither is particularly well known. Like many Mediterranean helicids, they escape from the daytime heat at ground level by climbing walls and rock faces, even though this may result in direct exposure to the sun. Duval & Giovenazzo (1989) have shown that for *O. lactea*, the closure of the umbilicus and flaring of the outer lip are indicative of reproductive maturity.

Theba pisana (Müller, 1774)

(white garden snail, sandhill snail, vine snail, dune snail, white Italian snail, duineslak)

Figures 32, 33

Helix pisana Müller 1774: 60; Melvill & Ponsonby 1898: 184; Fuller 1906: 446; Connolly 1912: 162; 1916: 187; Gunn 1924.

Helix (*Euparypha*) *pisana*; Boettger 1910: 456.

Theba pisana; Connolly 1939: 268; Dürr 1946; Barnard 1951: 148, pl. 22, fig. 7; Joubert & Walters 1951; Van Bruggen 1964: 162, 1970: 469; Swart *et al.* 1976: 190; Hickson 1972; Noyce 1973; McQuaid *et al.* 1979; Macdonald & Richardson 1986: 82; Sacchi 1996; Odendaal *et al.* 2008.

Euparypha pisana; Quick 1952: 183.

Type loc.: '*In Italia*'.

Description: Spire rather low, shell wider than high; whorls 4–5, rounded, but usually with a slight angle level with suture (more prominent in juveniles); suture only shallowly indented; sculpture of microscopic growth-lines and incised spiral lines; umbilicus present, but small and partly concealed by reflected inner lip of aperture; aperture lip not flaring outward in adult, but interior of outer lip frequently with a slightly thickened ridge set back from the edge. General colour dirty white to pale ginger, usually with numerous rather uneven, interrupted dark brown spiral lines, but some specimens more uniformly pale (Figure 32E); inner lip frequently tinged with pink; apex frequently dark purplish brown. Diameter 12–25 mm, but mostly less than 20 mm.

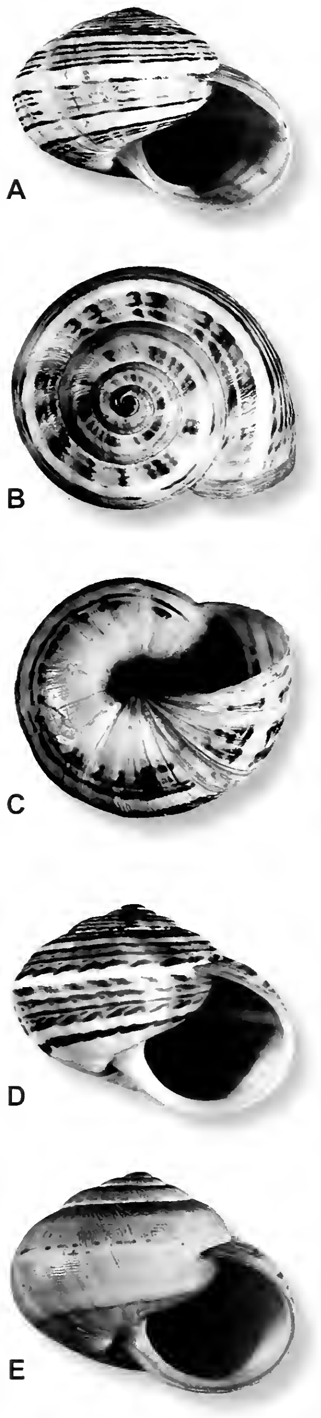
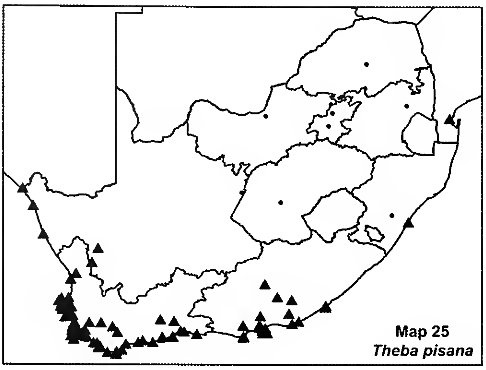


FIGURE 32.—*Theba pisana* (Müller, 1774). A–C, Bergvliet, Cape Town, apertural view, diameter 20.1 mm, apical view, 18.7 mm, basal view 18.4 mm (NMSA V8265 [2000]); D, dark specimen, Forest Hill cemetery, Port Elizabeth, E. Cape, diameter 17.4 mm (NMSA V8615 [2000]); E. pale specimen, Vermont saltpan, Hermanus, W. Cape, diameter 18.0 mm, (NMSA V8322 [2000]).



Habitat: A bush-dwelling species of coastal habitats in the Mediterranean region. In South Africa it occurs chiefly in the winter and all-year rainfall areas in the western and southern Cape, living primarily near the coast, in a variety of habitats, from gardens, road verges, pastures, grainlands and vineyards, to relatively pristine coastal fynbos (e.g. West Coast National Park).

Date of introduction: Prior to 1881. The earliest known South African material was collected at Gallows Hill (now part of Cape Town docks) in 1881 (Connolly, 1912).

First SA record: Melvill & Ponsonby (1898), Port Elizabeth, E. Cape and Cape Town, W. Cape.

Global distribution: Originally circum-Mediterranean, but now spread by human agency to other parts of western Europe, as far north as Britain and the Netherlands (Kerney 1999). Introduced also to California (Mead 1971a), southern Argentina, Bermuda (Bieler & Slapcinsky 2000), Azores (Backhuys 1975), Madeira (Seddon 2008), many parts of southern Australia (Baker 1986) and Tasmania (Kershaw 1991).

Distribution in SA (Map 25): Primarily coastal and recorded from many localities along the western and southern Cape coast, from the Orange River mouth to East London, with two additional (old) records from Durban and Maputo. Recorded inland as far as Loeriesfontein (Succulent Karoo), and the Swartberg and Cradock (Nama Karoo). Quick (1952) also listed Damaraland, Kaokoveld and Ovamboland in Namibia.

Pest status: *Theba pisana* is undoubtedly an agricultural and garden pest in the southern and western Cape where population densities can be extremely high. However, there

is little published information available and no quantitative data concerning its impact. A range of host plants are recorded, including vegetables, cereals, ornamental flowers and shrubs, deciduous and citrus fruit trees, berries and vines (Gunn 1924; Swart *et al.* 1976; Myburgh 1986–90; Schwartz 1988; Ferreira & Venter 1996; Joubert & Du Toit 1998). Mead (1971a) reported up to 3 000 snails on a single citrus tree. The role of *T. pisana* as a pest, however, is not restricted to agricultural crops. Dürr (1946) also noted that *T. pisana* infestation of indigenous shrubs important as pasture, not only damaged the leaves and bark of the plants, but rendered them unpalatable to livestock. In favourable areas, such infestations can be extremely heavy.

In addition to direct effects on crops and pasture, *T. pisana* may be a pest as a result of crop contamination. This is particularly so in cereal crops where the aestivating snails climb to the tops of the cereal heads and are then harvested, together with the grain, at the end of the season. Not only do the crushed bodies and mucus contaminate the crop and result in its down-grading by quality control inspectors at the point of sale, but the mucus-rich bodies mix with the dust and debris inside the harvester, and set into a cement-like substance which clogs the sieving plates. This necessitates that these be stripped and cleaned, resulting in costly delays. Such problems have not been well documented in South Africa, but they are of major concern in South Australia (Baker 1986: Coupland 1996; S. Charwat pers. comm.). However, *T. pisana* may not be the only snail involved, *Cernuella virgata* and *Cochlicella acuta*, which have similar aestivation habits, may be as troublesome if not more so (Baker 2002). All three co-occur at some South Australian sites. Control options for *T. pisana* have been discussed by Dowell *et al.* (1987) and Baker (2002).

As well as being a pest itself, *T. pisana* is known to assist in the dispersal of plant pathogens, such as the fungus *Colletotrichum lagenarium*, a pest of melons (Hasan 1976) and is intermediate host to a number of platyhelminth and nematode parasites of poultry, cattle and sheep (USDA 1999; Spratt 2005). *T. pisana* has reportedly been eradicated twice in California, in the early and mid-1900s (Mead 1961, 1971a), but by 1985 populations were found for a third time and it is now a well-established pest there.

Impact on indigenous ecosystems: The ecological impacts of *Theba pisana* in the natural communities into which it has spread in South Africa is a subject warranting further study. In view of the high population densities that can build up, for example in the sensitive fynbos communities in the south-western Cape, these impacts may be significant. Roberston *et al.* (2000) have modelled the potential distribution of *T. pisana* in South Africa using existing records and climatological data, and have shown the most favourable areas for colonisation coincide largely with the Fynbos Biome. Such modelling has not yet included edaphic variables relating to regional geology, but it is likely that calcium-rich environments such as the limestone and calcrete deposits of the Agulhas plain and Saldanha area will provide environments particularly prone to invasion by *T. pisana*. In a study of *T. pisana* in the West Coast National Park, Odendaal *et al.* (2008) found the snail to be most abundant in areas adjacent to roads and in highly disturbed areas. They listed a number of indigenous strandveld plants on which snails were found resting and which showed evidence of extensive damage, and concluded that the potential impact of the species is a cause for concern needing further investigation.

Furthermore, Smallridge & Kirby (1988) have shown that *T. pisana* is able to out compete and exclude another Mediterranean alien, *Cernuella virgata*, in South Australia, which raises concerns about its competitive interactions with our indigenous snail fauna. Connolly (1939) speculated that *T. pisana* may have been responsible for the extinction of the indigenous *Trachycystis rariplicata* (Pfeiffer, 1849), known only from the Green Point area of Cape Town. However, to definitively ascribe this extinction to *T. pisana*, when there must have been many other contributing factors in such a transformed area, is not justified. Serventy & Storr (1959) noted that on Rottnest Island (W. Australia), the indigenous snail *Bothriembryon melo* (Quoy & Gaimard, 1832) was rare or absent in areas infested by *T. pisana*, but more common where the latter was absent.

Similar indigenous species: None.

Notes: Highly invasive; particularly common in the southern and western Cape. The subtropical, summer rainfall climate of the eastern seaboard is evidently not favourable for these snails and the Durban and Maputo records probably represent isolated translocated individuals or small ephemeral colonies rather than established populations. No subsequent records are available for the east coast north of East London.

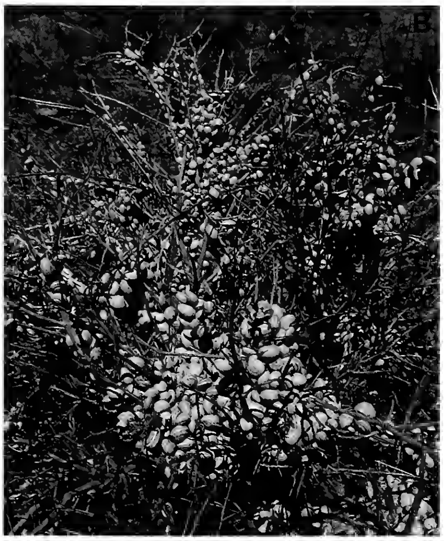


FIGURE 33.—*Theba pisana* (Müller, 1774) aggregations in the West Coast National Park. A, on fence post; B, on indigenous strandveld shrub. (B courtesy of Prof. C. Griffiths).

As a result of its status a major agricultural pest in Australia (Baker 1986), *T. pisana* has been extensively studied by scientists at the CSIRO and South Australian Research and Development Institute, Adelaide. In Europe it is generally semelparous, having only one reproductive period, after which most individuals die. This period, however, may occur either within the first year of life (annual) or only during the second year (biennial). In Britain, with generally colder, wetter summers, the life cycle is biennial (Cowie 1980, 1984). In Israel, with long dry summers, it is largely annual (Heller 1982), although under some conditions, a small portion of the population enters the dormant aestivation phase at an early age and may live for two years, reproducing only during the second one (Avivi & Arad 1993; Arad & Avivi 1998). Similar observations are reported in South Australia where some populations are annual and others biennial, although again the most common strategy appears to be a mixture of the two, resulting in two cohorts of progeny, thus enhancing population persistence under adverse conditions (Baker & Vogelzang 1988). Cowie (1984) suggested that a biennial cycle was advantageous when the duration of dormancy (hibernation or aestivation) was long and was thus favoured in the drier Mediterranean and colder northern regions (Britain). Such a hypothesis fits with the situation in South Africa, where Sacchi (1996) found that coastal populations (relatively mild climate) are largely annual, whereas those occurring more inland (harsher, drier climate), are biennial. Odendaal *et al.* (2008) also found coastal populations to be annual, but Baker & Vogelzang (1988) found the reverse in South Australia. Those snails following an annual cycle are evidently capable of reproducing well before reaching full size and even half-grown snails (diameter 10 mm) have been shown to be reproductively competent (Cowie 1980).

The breeding season begins in late summer to autumn when mating occurs after aestivation is broken by the first heavy rains of the season. Egg-laying extends until late winter, with hatching occurring during late winter and spring. Subsequent growth of the offspring may be rapid if the reproductive cycle is to be completed within one year, but slower and with longer dormant periods if biennial. Similar observations have been reported under laboratory conditions in South Africa, with egg-laying peaking in April and May, and hatching occurring some 13–30 days later (Dürr 1946). Reports of snails surviving for up to four years (Joubert & Walters 1951) probably represent extreme cases since the bulk of snails die after reproducing.

Like many other Mediterranean snails, *T. pisana* exhibits behavioural adaptations which help it to survive the hot dry summer. These adaptations and the temperature tolerances of the species were investigated by McQuaid *et al.* (1979), who demonstrated that the snails must maintain an average body temperature of well below 44°C during the hottest times of the day. Since temperatures

at ground level frequently exceed this, the snails climb upwards and aestivate above the ground where temperatures are lower. In parts of the W. Cape, *T. pisana* may adorn shrubs, bushes, fence-posts and telegraph poles in vast numbers (Figure 33). When the snails cannot find completely shaded sites within bushes and shrubs, they tend to congregate on the more shaded south and west-facing surfaces, almost always with the aperture of the shell uppermost. This strategy may not be effective on iron posts, on which the snails have been found congregating on the northern surface, perhaps insulating the post from the sun (W. Sirgel pers. comm.).

Colour polymorphism in *T. pisana*, ranging from heavily banded with a dark apex to almost white with a pale apex, has been studied in some detail. The variation is genetically based and is maintained by natural selection. In open habitats snails with a pale shell are at a selective advantage due to the greater reflectivity of the shell and the frequency of the unbanded morph is higher there than in shrubby habitat with more shaded resting sites (Johnson 1980). The snails also show some ability to choose aestivation sites, the darker ones migrating from open to shrubby habitats at the start of the dry season and choosing more often to rest within the shade of the shrub canopy, rather than at its edge (Johnson 1981; Hazel & Johnson 1990).

Analysis of movement patterns of *T. pisana* between roadside vegetation and pasture shows the former to constitute an important dry season aestivation refuge. A fact which could be exploited for the purposes of snail control (Baker 1988a).

SLUGS

Slugs are simply snails that have followed an evolutionary trajectory involving progressive reduction of the shell. Some families, such as the Testacellidae, retain a small external shell, but in most the shell is either vestigial and entirely internal or completely lost. This process has occurred independently in many terrestrial gastropod lineages and the 'slugs' as a whole do not constitute a recognised evolutionary entity. Nonetheless, for the purposes of identification it is pragmatic to treat them collectively. Although reduction and loss of the shell renders slugs more susceptible to predation and desiccation, there are other compensations and the slug body form can, under certain circumstances, be a highly successful life-history strategy. A fact clearly illustrated by their diversity and frequent abundance, and their success as synanthropic travellers.

Family: Testacellidae Gray, 1840

Body elongate and anteriorly tapering, lacking an obvious mantle shield, but with a small, ear-shaped shell situated near posterior extremity; well-developed, branching grooves extend anteriorly from beneath front of shell, along sides of body; head small.

A family of characteristic slugs belonging to a single genus, *Testacella* Draparnaud, 1801, native to the western Palaearctic. Carnivorous, lacking a jaw, but with a well-developed buccal mass, the radula bearing large, curved, sharply pointed teeth with apical barbs. Primarily subterranean, feeding at night, mostly on earthworms, but occasionally also other soft-bodied soil invertebrates, including snails and slugs. During cold or dry weather, they enclose themselves in a well-buried cocoon of hardened mucus and soil.

Testacella species have been recorded as introduced taxa in many temperate countries, but records are generally few and the species identity of old records often suspect. Further information on the anatomy, reproduction, ecology and feeding can be found in Watson (1915), Quick (1960) and Crampton (1975).

Testacella maugei Férussac, 1819

(Maugé's shelled slug)

Figure 34

Testacella maugei Férussac 1819: 94, pl. 8, figs 10, 12.

Testacella aurigaster Layard ms; Melvill & Ponsonby 1898: 166; Collinge 1901: 234; Connolly 1912: 64; Watson 1915: 221.

Testacella maugei; Watson 1915: 220; Connolly 1916: 182; 1939: 117; Barnard 1951: 155, pl. 20, fig. 6; Van Bruggen 1964: 162.

Type loc.: Tenerife, Canary Islands.

FIGURE 34.—*Testacella maugei* Férussac, 1819, Carbis Bay, St Ives, Cornwall, UK, length ± 60 mm (image courtesy of Dr Roy Anderson).

Description: A typical testacellid slug with a relatively large shell (12–16 mm long), the lateral body grooves are well separated where they emerge from beneath the shell. Brown, flecked with black dorsally, occasionally grey, rufous, greenish brown or black, with two longitudinal rows of paler tubercles along dorsal midline; sides paler, sole often pink or orange. Extended length 60–100 mm.

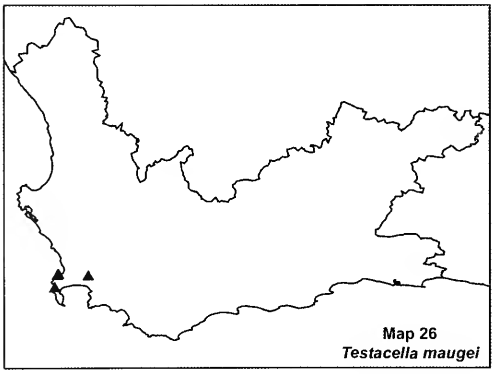
Habitat: Generally synanthropic, preferring rich cultivated soils with abundant earthworms. Little habitat data available for South African specimens, but mostly found in suburban gardens (Watson 1915). In Stellenbosch it favours rich, dark topsoil (W. Sirgel pers. comm.).

Date of introduction: Prior to 1872 (see notes below).

First SA record: Melvill & Ponsonby (1898, as *Testacella aurigaster*), Cape Town, W. Cape.

Global distribution: Native to western Europe, Morocco and the islands of the north-eastern Atlantic. Quick (1960) considered it native in SW England, but Kerney (1999) suggested it was probably an introduction in Britain. Introduced also to North America (Quick 1960). Records from New Zealand are thought to represent *T. haliotidea* Draparnaud, 1801 (Barker 1979, 1999).

Distribution in SA (Map 26): Recorded only from Cape Town, the Cape Peninsula (Noordhoek) and Stellenbosch.



Pest status: Not pestiferous, although some may consider its largely vermivorous diet undesirable in gardens.

Similar indigenous species: Indigenous slugs of the family Chlamydephoridae lead a similar carnivorous and largely subterranean existence, but in these the shell is even more reduced and is entirely internal.

Notes: Watson (1915) has discussed in detail the issue of the manuscript name *Testacella aurigaster* Layard, and there can be little doubt that it equates to the introduced *T. maugei*. In so doing Watson quoted an undated manuscript note written by Edgar Layard, in which he stated, *inter alia*, that the species 'was common in the grounds of the South

African Museum'. Since Layard was Curator/Director of the South African Museum from 1855–1872, after which he left for South America, it seems logical to assume that the material was collected prior to 1872.

Recorded in South Africa on very few occasions and most literature records refer in fact to the same material, namely that collected by Layard in Cape Town in the late 19th century. The Noordhoek record, however, is more recent (1999). Probably under-recorded on account of its habits.

Family: Milacidae Ellis, 1926

Mantle present in mid-anterior region and bearing a characteristic, horseshoe-shaped groove; pneumostome on right, posterior to mid-point of mantle shield; posterior portion of body with a mid-dorsal keel extending from tip of tail to hind margin of mantle shield; foot divided longitudinally into three bands, the central one of which has a herring-bone pattern; tail pointed; internal shell present.

The family Milacidae is native to Europe and North Africa (Wiktor 1987), and is so far represented in South Africa only by *Milax gagates*. It is quite possible, however, that other milacids have been or will be introduced into the country, but have not yet been recorded. Consequently, it would be safest to consult the literature on European slugs (e.g. Kerney & Cameron 1979; Wiktor 1987) before making definitive identifications. *M. gagates* is similar to *M. nigricans* (Schultz, 1836) and the two species have often been confused. Whether some South African records in fact represent *M. nigricans* needs to be investigated.

Connolly (1939) referred two indigenous South African slug species to *Milax*, namely *M. capensis* (Krauss, 1848) and *M. ponsonbyi* (Collinge, 1900). However, Sirgel (1985) has subsequently referred both to his new genus *Ariopelta*.

Milax gagates (Draparnaud, 1801)

(jet slug, black keeled slug, small black slug, greenhouse slug)

Figure 35

Limax gagates Draparnaud 1801: 100.

Amalia gagates; Melvill & Ponsonby 1898: 172; Collinge 1900: 2; 1901: 230, 234.

Milax gagates; Collinge 1910: 161; Connolly 1912: 120; 1916: 184; 1939: 180; Barnard 1951: 156, pl. 20, fig. 9; Quick 1952: 188; Van Bruggen 1964: 162; Altena 1966: 289; Els 1974; Wiktor 1987: 202 (further references and synonymy); Herbert 1997: 220, fig. 33; Herbert & Kilburn 2004: 295.

Type loc.: southern France (perhaps Montpellier).

Description: A relatively smooth-skinned, dark grey to black slug (rarely paler brown), easily recognised as a milacid by the prominent keel running from the tail to the hind end of the mantle shield and the horseshoe-shaped groove on the mantle shield itself; the coloration, though paler towards the foot, is relatively uniform (not spotted or banded). Extended length up to 60 mm.

Habitat: In Europe the species is common in modified habitats such as gardens and ruderal habitats, but also occurs in natural habitats, particularly near the coast (Quick 1960; Kerney 1999); generally under logs, stones, and other objects lying on the ground in shaded areas. Largely synanthropic outside its native range. South African records are mostly from gardens, plant nurseries and croplands.

Date of introduction: Prior to 1873 [the visit of '*Challenger*', 28 Oct.–17 Dec., 1873)']

First SA record: Smith (1884, as *Limax gagates*), Cape Town, W. Cape ['*Challenger*' Expedition].

Global distribution: Thought to be indigenous to coastal areas of the western Mediterranean, including North Africa, and perhaps the Canary Islands and Azores (Wiktor 1987). Introduced widely to other regions, including the USA (Pilsbry 1948; Chichester & Getz 1969), Brazil, Chile, Ecuador, Peru and Uruguay (Quick 1952; Stuardo & Vega 1985; Ramírez *et al.* 2003; Scarabino 2003; Simone 2006), Columbia (Hausdorf 2002), Bermuda (Bieler & Slapcinsky 2000), St Helena (Crowley & Pain 1977), Ascension (Quick 1952), Tristan da Cunha (Preece 2001), northern Europe (Kerney 1999), Sri Lanka (Naggs *et al.* 2003), Japan (Barker 1999), Australia (Cotton 1954), Tasmania (Kershaw 1991), New Zealand (Barker 1979, 1999), Hawaii (Cowie 1997), islands in the southwestern Pacific (Cowie 2000) and Easter Island (Bokyo & Cordeiro 2001).

Distribution in SA (Map 27): Recorded from the W. Cape (Amalienstein [near Ladismith],

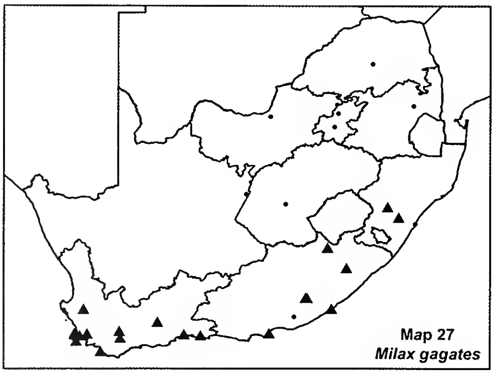
FIGURE 35.—*Milax gagates* (Draparnaud, 1801), Halstone Farm, north of Barkly East, length ± 50 mm (NMSA W6768 [2009]).

Ashton, Caledon, Cape Town, Cape Flats, Gansbaai, George, Knysna, Moorreesburg, Simonstown, Stellenbosch and Storms Vlei), E. Cape (Barkly East area, East London, Hogsback, Langeni and Port Elizabeth) and KwaZulu-Natal (Mooi River and Pietermaritzburg).

Pest status: Recoded as damaging rare native plants in Hawaii (Cowie 1997), and considered a pest of pasture in New Zealand (Barker 2002b). Known to feed on soft plant material and has the potential to become a pest of fruit, root and tuber crops, sunflower, maize, cereals, pasture and newly-sown crops in general (Wiktor 1987; South 1992; Barker 1999, 2002b; Glen & Moens 2002; Hommay 2002). Reported to be an episodic pest of canola, barley and wheat in the southern Cape (G. Tribe pers. comm. 2007) and lucerne (W. Sirgel pers. comm.).

Similar indigenous species: *Ariopelta capensis* (Krauss, 1848) [Oopeltidae] has been confused with this species, but Sirgel (1985) has shown that the two are distinct. In *A. capensis* the dorsal keel is less prominent, the foot sole undivided and the slit in the mantle edge passes through the centre of the pneumostome instead of through its anterior edge as in *M. gagates*. *A. capensis* is evidently a rare species, recorded only from the Hottentots Holland mountains, southwestern Cape.

Notes: Under laboratory conditions, the life cycle is completed in six to nine months, with egg-laying occurring in spring and autumn, after which the slugs die (Focardi & Quattrini 1972; Barker 1999).



Family: Agriolimacidae Wagner, 1935

Small, fawn to dark brown slugs that resemble garden slugs (Limacidae), particularly species of *Lehmannia*, but generally smaller (mostly < 45 mm long at adult size) and lacking distinct dark longitudinal bands. Mantle shield with fine concentric ridges resembling a fingerprint, the central point of which lies to the right of mid-line, just above pneumostome; posterior mantle pore lacking; pneumostome on right, behind mid-point of mantle shield; vestigial internal shell present; posterior portion of tail with short, indistinct keel; tail tip steeply sloping; foot sole longitudinally tripartate.

All agriolimacid slugs occurring in South Africa belong to the genus *Deroceras* and have been introduced from Europe. They are herbivorous and can be serious pests particularly of market garden vegetables. It is this association with human food crops that has no doubt contributed to their rapid spread, even into natural habitats. An additional factor enhancing their capacity to spread and invade is their ability to reproduce by self-fertilisation (perhaps even by parthenogenesis)—one slug is thus enough to start a new colony.

Genus *Deroceras* Rafinesque, 1820

(field slugs)

Three species of *Deroceras* have been recorded in South Africa, *D. laeve* (Müller, 1774), *D. panormitanum* (Lessona & Pollonera, 1882) and *D. reticulatum* (Müller, 1774), the first most frequently. Accurate species discrimination is not easy and requires dissection of the reproductive tract, even then identification may remain speculative because of the frequent occurrence of juveniles and aphallic individuals. Such aphallic specimens have traditionally been referred to *D. laeve* (Kerney & Cameron 1979; Wiktor 2000), but the reliability of this assumption has been questioned (De Winter 1988b; Reise *et al.* 2006), as has the utility of some of the external characters traditionally used to differentiate the species, particularly those separating *D. laeve* and *D. panormitanum*.

Some of the South African *Deroceras* material available is either immature or aphallic and its identity thus somewhat dubious. It is, however, clearly referable to the genus *Deroceras*. Unlike most other alien slug species in South Africa, which are largely synanthropic (even though they may occur in rural areas), *Deroceras* species have dispersed beyond human settlements into more or less pristine indigenous habitats.

Globally, the genus is distributed over most of Eurasia and North America, with perhaps as many as 120 species. A detailed revision was provided by Wiktor (2000). Although only three species are currently recorded as aliens in South Africa, it is quite possible that others have been, or will in due course be introduced. Widely known in the older literature under the name *Agriolimax* Mörch, 1865.

Key to identification of *Deroceras* species recorded from South Africa

- Small (up to 25 mm long), generally of a dark, relatively uniform colour often with inconspicuous darker flecks; mantle shield approx. half of anterior mantle-to-tail length; mucus clear; body wall translucent; crawls actively. Penis long, sometimes twisted, with an unbranched apical penial gland (but most individuals partially or almost completely aphallic); penis stimulator in basal portion of penis small and rounded; rectal caecum absent.... **laeve**

- Small (up to 35 mm long), generally of a relatively uniform colour often with inconspicuous darker flecks, but peri-pneumostomal area paler; mantle shield approx. 0.3–0.4 of anterior mantle-to-tail length; mucus clear; body wall translucent; crawls actively and frequently aggressive to other individuals. Penis large, with a swollen basal portion containing a well-developed conical stimulator; apical portion comprising two lobes between which is a tuft of 4–6 long, weakly nodular penial gland appendages; rectal caecum present but short .... **panormitanum**

- Medium-sized (up to 50 mm long), generally pale buff or grey frequently with conspicuous darker flecks, particularly in skin grooves; mantle shield approx. 0.3–0.4 of anterior mantle-to-tail length; mucus milky when irritated; body wall not translucent; less active. Penis large with a medial constriction; basal section with a well-developed elongate-conical stimulator; apical portion with penial gland comprising one large nodular appendage bearing 1–3 smaller nodular processes near its base; rectal caecum present, long .... **reticulatum**

NB. I have found it particularly difficult to distinguish between *D. laeve* and *D. panormitanum* using external characteristics alone. Some populations of the latter also closely resemble *D. reticulatum* in terms of body colour and markings. The most reliable and easily examined characters are those of the reproductive tract, which can be observed by simple dissection of the region between the right optic tentacle and the pneumostome, beneath the mantle shield. For the South African material discussed below, species discrimination has largely been based on features of the genitalia.

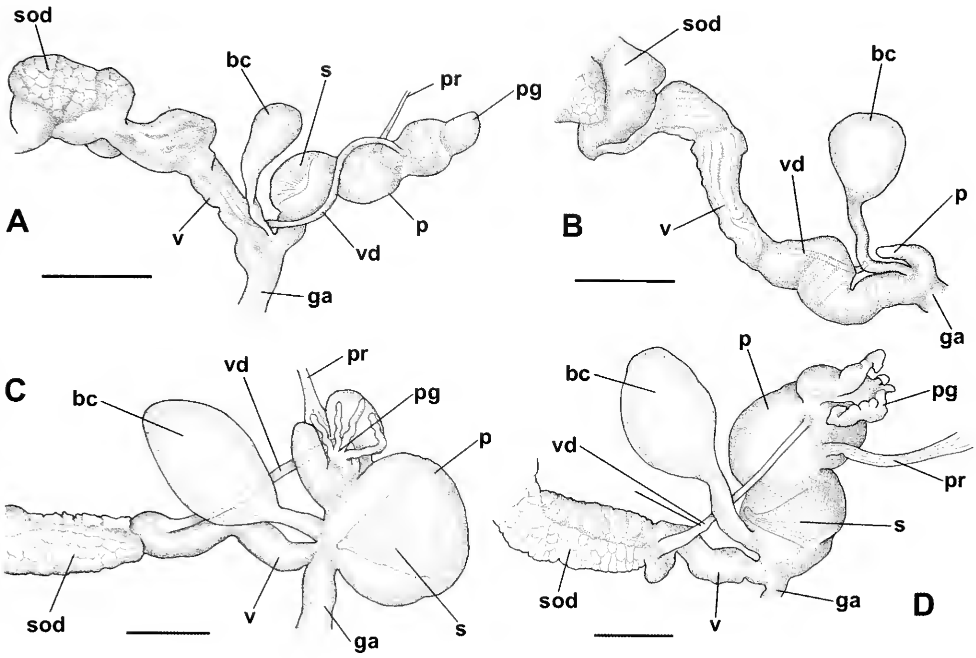


FIGURE 36.—Distal genitalia of *Deroceras* species. A, *D. laeve*, euphallic form, Hilton, Pietermaritzburg (NMSA W5960); B, *D. leave*, aphallic form, Pietermaritzburg (NMSA V5935); C, *D. panormitanum*, Orangekloof, Constantia (NMSA W5749); D, *D. reticulatum*, Kirstenbosch (NMSA W5746). **bc**, bursa copulatrix; **ga**, genital atrium; **p**, penis; **pg**, penial gland; **pr**, penial retractor muscle; **s**, stimulator; **sod**, spermoviduct; v, vagina; **vd**, vas deferens. Scale bars = 2.0 mm.

Deroceras laeve **(Müller, 1774)**

(marsh slug, smooth slug, brown slug, meadow slug)

Figures 36A,B; 37

Limax laevis Müller 1774: 1.

Agriolimax laevis; Sturany 1898: 36; Collinge 1901: 234; Connolly 1912: 122; 1916: 185; 1939: 179; Quick 1952: 188.

Deroceras laeve; Forcart 1963: 106; Altena 1966: 294; Van Bruggen 1966: 344; Els 1978; Herbert & Kilburn 2004: 299.

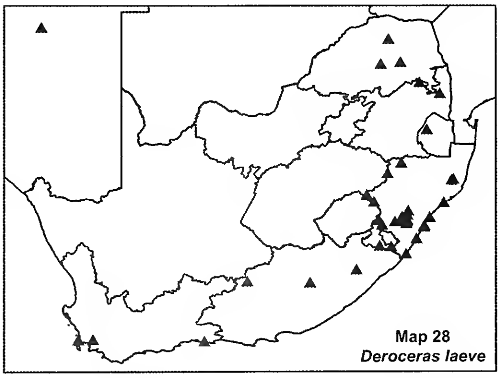
Deroceras laevis; Van Bruggen 1964: 162.

Type loc.: Frederiksdal, near Copenhagen, Denmark.

Description: A small, chestnut to dark brown slug, often with indistinct, darker spots; lacking darker longitudinal bands; peri-pneumostomal area only slightly paler; mantle shield relatively large, half of anterior mantle-to-tail length; posterior keel short and indistinct; mantle fingerprint relatively coarse; sole of foot paler brown, mucus colourless; crawls actively. Extended length rarely exceeding 22 mm, but often smaller than this even when mature.

FIGURE 37.—*Deroceras laeve* (Müller, 1774) Bisley Valley, Pietermaritzburg, KwaZulu-Natal, length ± 21 mm (NMSA V4091 [1997]).

Habitat: Generally associated with damp habitats in its native range, such as marshes, fens, flood-prone pasture, riverine vegetation and moist forest/woodland (Quick 1960; Kerney 1999; Wiktor 2000), but tolerant of a wide range of temperature regimes, as evidenced by its wide altitudinal and latitudinal distribution, from sea level to 3 500 m and from the tropics to subpolar regions. Many South



African records are from suburban and rural gardens, and other transformed habitats, but the species has also spread into a range of well-vegetated natural habitats.

Date of introduction: Prior to 1898.

First SA record: Sturany (1898), 'Cap'.

Global distribution: Native to the Holarctic, originating in the Palaearctic and thought to have spread naturally to the Nearctic in the Pleistocene. Introduced to many other parts of the world including Brazil (Simone 2006), Chile (Stuardo & Vega 1985), Columbia (Hausdorf 2002), Peru (Ramírez *et al.* 2003), Uruguay (Scarabino 2003), Venezuela (Arias 1959), Jamaica (Rosenberg & Muratov 2006), Azores (Backhuys 1975), Madeira (Seddon 2008), Tristan da Cunha and Inaccessible Island (Preece 2001), Israel (Roll *et al.* 2009), Kenya (Verdcourt 1972, 2006), Zaire (Backeljau *et al.* 1987), Mascarene Islands (Stévanovitch 1994; Griffiths 1994; Griffiths & Florens 2006), Comoros (Backeljau *et al.* 1987), Pakistan (Wiktor & Auffenberg 2002), Sri Lanka (Naggs *et al.* 2003), New Guinea (Wiktor 2000), New Caledonia (Solem 1964), Japan (Kano 2001), New Zealand (Barker 1999), Hawaii (Cowie 1997), Pacific islands (Cowie 2000). Barker & Pottinger (1983) considered it indigenous in the highlands of Central and South America, but this was disputed by Hausdorf (2002).

Distribution in SA (Map 28): Recorded from W. Cape (Cape Town area, Jonkershoek, Knysna), E. Cape (Langeni, Nieu-Bethesda, Queenstown), numerous localities in KwaZulu-Natal, Mpumalanga (Mariepskop), Kruger National Park (Skukuza) and Limpopo (Polokwane, Soutpansberg, Tzaneen). Also recorded from Namibia (Windhoek) (Van Bruggen & Rolán 2003) and Swaziland (Altena 1966).

Pest status: Recorded as a pest in legume, maize, vegetable and ornamental crops (e.g. orchids), and pasture, but evidently less problematic than *D. reticulatum* (Barker 2002b). May serve as a vector for human angiostrongyliasis (Hollingsworth *et al.* 2007).

Similar indigenous species: None

Notes: Barker (1979, 1999) considered that early records of *D. laeve* in New Zealand represented misidentifications of *D. panormitanum* (below), and this should be borne in mind in relation to South African records. The penis is reduced or absent (aphallic) in some specimens and some populations, and reproduction thus uniparental, either by self-fertilisation or parthenogenesis. Such aphallic individuals can be difficult to identify with confidence (see above). Duration of life cycle highly adaptable, but can be very short, less than six weeks under favourable conditions (Barker 1999; Wiktor 2000), when it can also reproduce throughout the year. Omnivorous; primarily herbivorous, feeding on live and dead plant material, but will scavenge on carrion and occasionally consume live soft-bodied invertebrates.

***Deroceras panormitanum* (Lessona & Pollonera, 1882)**

(brown field slug, long-necked field slug)

Figures 36C; 38

Limax [section *Agriolimax*] *panormitanus* Lessona & Pollonera 1882: 52, pl. 1, figs 5, 12.

Deroceras caruanae; Van Bruggen 1964: 162; Altena 1966: 293; Sirgel 1973.

Deroceras panormitanum; Herbert & Kilburn 2004: 299.

Type loc.: Palermo, Sicily.

Description: Coloration variable, frequently light- to mid-brown, somewhat translucent; often finely speckled with darker brown spots (some specimens distinctly so and resemble *D. reticulatum*), occasionally uniformly darker; dark longitudinal bands absent; peri-pneumostomal area conspicuously paler; mantle shield about 0.3-0.4 of anterior mantle-to-tail length; posterior keel short; sole of foot pale greyish, mucus thin and colourless; larger and more active than the externally similar *D. laeve*. Extended length up to 35 mm.

FIGURE 38.—*Deroceras panormitanum* (Lessona & Pollonera, 1882), Orangekloof, Table Mountain, W. Cape, length ± 30 mm (NMSA W5749 [2007]).

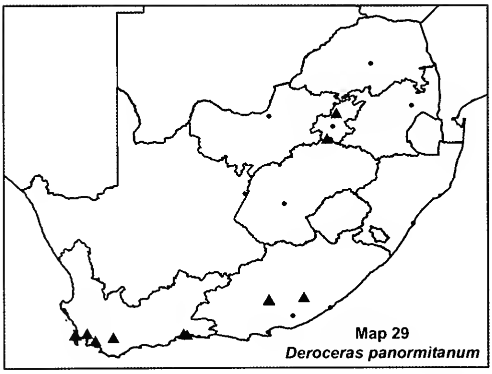
Habitat: In Europe *D. panormitanum* is common in modified and disturbed habitats such as gardens, parks, farmland, road verges and ruderal land, as well as in natural habitats such as shrubland, woods and coastal cliffs (Quick 1960; Kerney 1999; Wiktor 2000). In Australia it has invaded disturbed native bushland (Altena & Smith 1975). Most records in South Africa are from gardens, but the species has been found in indigenous forest on Table Mountain and near Somerset East.

Date of introduction: Prior to 1963 (Van Bruggen 1964), but see notes below.

First SA record: Van Bruggen (1964, as *D. caruanae*), George, W. Cape.

Global distribution: Probably Mediterranean in origin (Wiktor 2000), but has spread synanthropically into much of central Europe and Scandinavia. Introduced also to the USA (Pilsbry 1848; Chichester & Getz 1969; Reise *et al.* 2006), Canada (Rollo & Wellington 1975, Forsyth 2004), Columbia (Hausdorf 2002), the Azores (Backhuys 1975; De Winter 1988b), Madeira (Seddon 2008), Canary Islands (Altena 1966),Tristan da Cunha and Inaccessible Island (Preece, 2001), Marion Island (Smith 1992), Australia and Tasmania (Altena & Smith 1975; Kershaw 1991; Smith 1992) and New Zealand (Barker 1999).

Distribution in SA (Map 29): Recorded from several localities in W. Cape (Cape Peninsula, George, Houhoek, Riviersonderend Mountains, Stellenbosch and Wilderness), E. Cape (Hogsback and Somerset East) and Gauteng (Pretoria and Vanderbijlpark).



Pest status: Considered a pest in pasture, commercial crops, suburban gardens, nurseries and greenhouses (Altena & Smith 1975; Barker 1999, 2002b).

Similar indigenous species: None

Notes: Feeds on both living and dead plant material. Tends to be aggressive toward other individuals, readily biting them and frequently cannibalistic, even when food is plentiful. Breeds throughout the year when conditions are favourable. Mating behaviour is similar to that of *D. reticulatum* (see below) often involving much biting and tail lashing (Barker 1999).

There has been some uncertainty and controversy surrounding the correct name for this species. Although long known as *Deroceras*

caruanae (Pollonera, 1891), and first recorded in South Africa under this name (Van Bruggen 1964), following Giusti (1986), European specialists now consider *D. caruanae* to be indistinguishable from *D. panormitanum* and *D. pollonerae* (Simroth, 1889) [but see also Van Goethem & De Wilde 1984]. Being the oldest name, *D. panormitanum* has priority. Altena (1966) speculated that slugs recorded from Pietermaritzburg and Namibia by Connolly (1939) as *Agriolimax laevis* var. *grisea* Taylor, 1906, might represent this species, in which case the date of introduction would predate 1939.

Deroceras reticulatum (Müller, 1774)

(grey field slug, reticulate slug, milky slug)

Figures 36D; 39

Limax reticulatus Müller 1774: 10, N° 207.

Agriolimax agrestis (*non* Linnaeus, 1758); Melvill & Ponsonby 1898: 172; Collinge 1900: 3; 1901: 234; 1910: 161; Connolly 1912: 121; 1916: 184; 1939: 178.

Agriolimax reticulatus; Barnard 1951: 156, pl. 20, fig. 11; Quick 1952: 188.

Deroceras reticulatus [*sic*]; Van Bruggen 1964: 162.

Deroceras reticulatum; Altena 1966: 293; Herbert & Kilburn 2004: 299.

Type loc.: '*In horto Rosenburgensi & Fridrichdalensi*' near Copenhagen, Denmark.

Description: A medium-sized slug of variable colour, but commonly buff to brown or occasionally dark grey; usually with darker brown to black flecks, particularly in the superficial skin grooves; mantle shield about 0.3–0.4 of anterior mantle-to-tail length, also with darker flecks or blotches; peri-pneumostomal area slightly paler; posterior keel short and indistinct; foot sole usually pale, mucus clear but milky when irritated; larger and less active than either *D. laeve* or *D. panormitanum*, and appearing less translucent. Extended length up to 50 mm.

Habitat: Occurs in a wide variety of habitats in its native range, including grassland and hedgerows, but is particularly common in pasture, root crops, wasteland, road verges, suburban gardens and parks, refuse dumps and compost heaps, less often in wooded habitats (Quick 1960; Barker 1999; Kerney 1999; Wiktor 2000). In South Africa it is recorded mostly from gardens, but has also been found in grassland, exotic forestry plantations and indigenous forest.

Date of introduction: Prior to 1898.

First SA record: Melvill & Ponsonby (1898, as *Agriolimax agrestis*), Cape Town, W. Cape.

Global distribution: Native to Europe, but its original distribution unclear and now widely distributed on that continent. Introduced also to the USA (Pilsbry 1948; Branson 1980), Canada (Rollo & Wellington 1975; Forsyth 2004), Brazil, Chile, Columbia, Peru and Uruguay (Quick 1952; Stuardo & Vega 1985; Hausdorf 2002; Ramírez *et al.* 2003; Scarabino 2003), the Azores (Backhuys 1975; De Winter 1988b), Madeira (Seddon 2008), St Helena (Crowley & Pain 1977), islands of the South Atlantic and sub-Antarctic (Preece 2001; Smith 1992), Israel (Roll *et al.* 2009), central Asia (Wiktor 2000), Sri Lanka (Naggs *et al.* 2003), Réunion (Stévanovitch 1994; Griffiths & Florens 2006), Australia and Tasmania (Altena & Smith 1975; Kershaw 1991; Smith 1992), New Zealand (Barker 1999), Hawaii (Cowie 1997), islands in the south-western Pacific (Cowie 2000) and Easter Island (Bokyo & Cordeiro 2001).

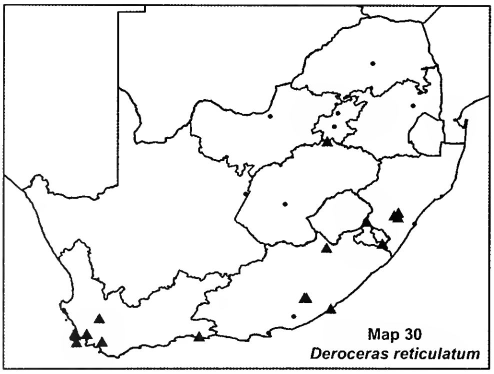
Distribution in SA (Map 30): Recorded from several localities in W. Cape (Caledon, Cape Peninsula, Cape Town, Ceres, Knysna and Stellenbosch), E. Cape (Barkly East area, East London and Hogsback), Free State (Sasolburg area) and KwaZulu-Natal (Albert Falls, Drakensberg Gardens, Harding area, Hilton and Pietermaritzburg).

Pest status: A serious pest in a wide range of agricultural and horticultural crops, as well as in domestic gardens (South 1992; Barker 2002a, b).

Similar indigenous species: none

Notes: A non-specific herbivore, feeding on a wide variety of living and dead plant material, including, leaves, fruit, seedlings, seeds, roots and tubers. Lives for approximately nine months to one year, with a complex and evidently variable life cycle, depending on conditions, but with two main breeding seasons, the young hatching in late spring and early autumn (South 1992; Barker 1999; Wiktor 2000). Reproduction generally by outcrossing, rarely by self-fertilisation. Mating is preceded by a complex courtship during which the partners circle around one another, and caress each other with the extended

FIGURE 39.—*Deroceras reticulatum* (Müller, 1774), Oubos Forest, Riviersonderendberg, W. Cape, length ± 45 mm (NMSA W5752 [2007]).



stimulator (sarcobelum), prior to eversion and intertwining of the penes, and exchange of seminal fluids. Up to 500 eggs may be laid in one year, with a mean of 22 eggs per clutch (for further details see South 1992 and Barker 1999, and references therein).

Frequently confused with *D. agreste* (Linnaeus, 1758) and often identified under that name by earlier workers who did not distinguish between the two species.

Family: Limacidae Lamarck, 1801

Medium-sized to very large slugs (up to 200 mm long); mantle shield bearing fine concentric ridges, somewhat resembling a fingerprint, this pattern centred about the mid-line (compare Agriolimacidae); posterior mantle pore lacking; pneumostome on right, behind mid-point of mantle shield; a thin, fragile vestigial internal shell retained under the mantle shield; tail region with weak dorsal keel in mid-line, but keel not extending to mantle shield (compare Milacidae); tail tip gently sloping; foot sole longitudinally tripartate.

All limacid slugs occurring in South Africa are introduced from Europe. These belong to three genera, namely *Limax* Linnaeus, 1758, *Limacus* Lehmann, 1864 and *Lehmannia* Heynemann, 1863, which differ from one another in details of gut and reproductive anatomy. *Limax* has no rectal caecum, whereas *Lehmannia* and *Limacus* have a long one; these in turn differ from one another in the position of the bursa copulatrix duct which opens into the genital atrium in *Lehmannia* and into the free oviduct in *Limacus* (Barker 1979). Externally, however, *Limacus* more closely resembles *Limax* and the species have often been treated under the latter name. Species of *Lehmannia* resemble agriolimacid slugs (*Deroceras*), but are generally larger (> 40 mm long), usually have a pair of dark, dorso-lateral longitudinal bands and a gently sloping tail, whereas our introduced *Deroceras* species are smaller (rarely > 40 mm long), have a steeply sloping tail and lack darker longitudinal bands. Furthermore, in *Lehmannia* the finger-print pattern on the mantle shield is centred about the mid-line (as in all limacids), but in *Deroceras* it is displaced to the right, just above the pneumostome.

Limacid slugs are primarily herbivorous and frequently cause damage to agricultural crops and garden plants. Reproductive behaviour sometimes involves complex courtship and mating rituals. In *Limax maximus* mating takes place at night and the copulating pair usually suspend themselves from vegetation on a mucus string, sometimes several metres above ground. In such a position they entwine their long penes and exchange sperm before climbing back up the mucus strand.

Lehmannia nyctelia (Bourguignat, 1861)

(vine slug, Bourguignat's slug, striped garden slug)

Figures 40; 41A

Limax nyctelius Bourguignat 1861: 305, pl. 2, figs 3, 4; Connolly 1939: 176; Quick 1960: 200, fig. 17, b, c, e; Forcart 1963: 107; Van Bruggen 1964: 162.

Limax (Limacus) nyctelius; Altena 1966: 290; Van Bruggen & Appleton 1977: 36.

Lehmannia nyctelia; Herbert 1997: 224, figs 35–37; Herbert & Kilburn 2004: 297

Type loc.: Algeria.

Description: Medium-sized, grey-buff to brown, somewhat translucent, usually with a pair of dark, dorso-lateral longitudinal bands, one on each side of mid-line, sometimes broken up into spots; mantle shield similarly marked, sometimes with a third band in mid-line; posterior keel short and not particularly obvious; sole pale grey; mucus colourless. Extended length 40–60 mm.

Habitat: In its native range *L. nyctelia* occurs in forest, wooded thickets and montane habitats; often climbing trees (Wiktor 1983, 1996). Most South African records are from suburban gardens, but it has also been found in rural areas and game reserves (Van Bruggen & Appleton 1977). In Australia, Altena & Smith (1975) recorded it as common in cleared open country and modified bush.

Date of introduction: Prior to 1939.

First SA record: Connolly (1939) from various localities in W. Cape, E. Cape and KwaZulu-Natal.

Global distribution: Native to central and eastern Europe (Grossu & Lupu 1965; Wiktor 1996). Although described from North Africa,

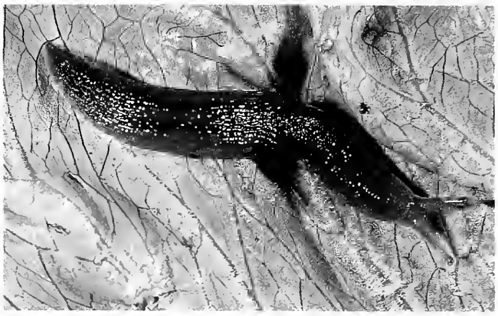
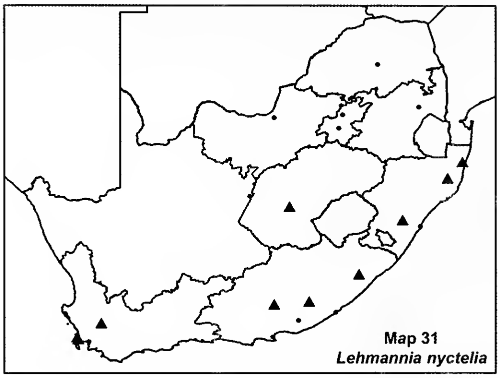


FIGURE 40.—*Lehmannia nyctelia* (Bourguignat, 1861), suburban garden, Pietermaritzburg, KwaZulu-Natal, length ± 46 mm (NMSA V2055 [1995]).



its occurrence there may result from introduction (Wiktor 1996). Introduced also to the USA (Quick 1960), Britain (Quick 1960), Réunion (Griffiths & Florens 2006), Australia (Altena & Smith 1975), Tasmania (Kershaw 1991) and New Zealand (Barker 1979, 1999).

Distribution in SA (Map 31): Recorded from W. Cape (Cape Town, Ceres), E. Cape (Hogsback, Somerset East, Mthatha), Free State (Bloemfontein), and KwaZulu-Natal (Hluhluwe Game Reserve, Mbazwana, Pietermaritzburg).

Pest status: Considered a significant pest in nurseries and gardens in New Zealand (Barker 1999), but otherwise seldom cited as a species of concern.

Similar indigenous species: None

Notes: Very similar to *Lehmannia valentiana* and cannot be reliably separated from it without dissection of the male reproductive tract. See description of *L. valentiana* below. Of the two, *L. nyctelia* seems to be much less common in South Africa.

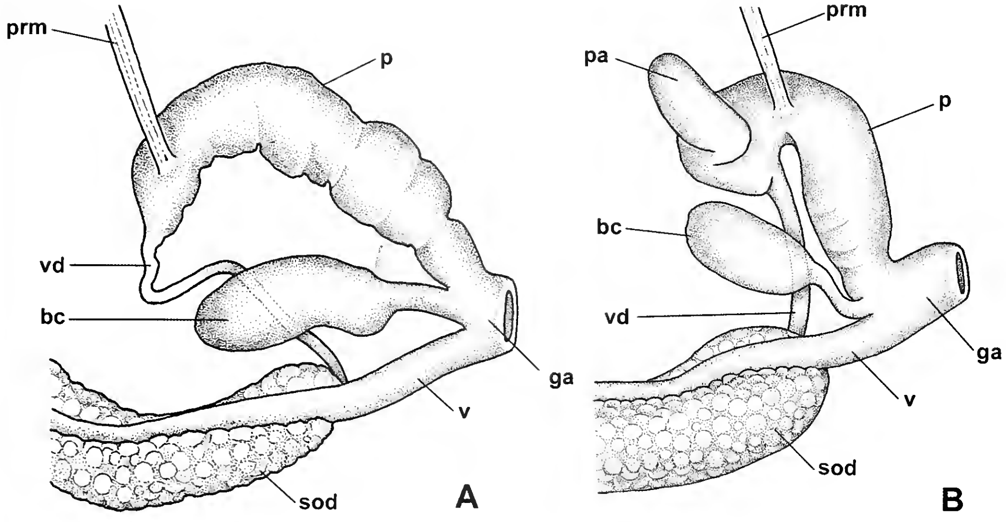


FIGURE 41.—Genitalia of *Lehmannia* species. A, *L. nyctelia*; B, *L. valentiana*. **bc**, bursa copulatrix; **ga**, genital atrium; **p**, penis; **pa**, penial appendage; **prm**, penis retractor muscle; **sod**, spermoviduct; **v**, vagina; **vd**, vas deferens.

Lehmannia valentiana (Férussac, 1822)

(three-banded garden slug, Valencia slug)

Figures 41B; 42

Limax valentianus Férussac 1822 in 1921–22: 21; Van Bruggen 1964: 162; Stears 1974.

Limax poirieri Mabille 1883; Quick 1960: 197, pl. 1, fig. 14.

Limax (Lehmannia) valentianus; Waldén 1962; Altena 1966: 292; Van Bruggen 1968: 51.

Lehmannia valentiana; Herbert 1997: 225, fig. 38; Herbert & Kilburn 2004: 297.

Type loc.: Valencia, Spain.

Description: Externally almost indistinguishable from *L. nyctelia* (above). Accurate identification requires dissection of the male genital tract. In *L. valentiana* the penis is relatively short and possess a short, blunt ending appendage (flagellum), whereas in *L. nyctelia* the penis is longer and lacks an appendage (compare Figures 41 A, B).

Habitat: Found in greenhouses, nurseries and botanical gardens in northern Europe and the USA (Waldén 1962; Kerney 1999), as well as in more open habitats; ground-dwelling, in sheltering microhabitats such as beneath stones and logs, and amongst plant debris. In South Africa most records originate from suburban and rural gardens, but there has been some spread into indigenous habitats in the greater Cape Town area.

Date of introduction: Prior to 1961 (Waldén 1962).

First SA record: Waldén (1962), Port Elizabeth, E. Cape [Van Bruggen].

Global distribution: Thought to be indigenous to the Iberian Peninsula (Waldén 1962). Now more widespread in western Europe and introduced also to the USA (Quick 1960; Chichester & Getz 1969; Branson 1980), Canada (Forsyth 2004), Brazil, Chile, Columbia and Peru (Stuardo & Vega 1985; Hausdorf 2002; Ramírez *et al.* 2003; Simone 2006), Azores (Backhuys 1975), Madeira (Seddon 2008), Tristan da Cunha and Gough Island (Preece 2001), Israel (Roll *et al.* 2009), China (Wiktor *et al.* 2000), Japan (Kano 2001, Kano *et al.* 2001), Australia (Waldén 1962), New Zealand (Barker 1999) and Easter Island (Bokyo & Cordeiro 2001). Distribution discussed in detail by Waldén (1962).

Distribution in SA (Map 32): Recorded from W. Cape (Cape Town area, Gansbaai, George and Stellenbosch), E. Cape (Barkly East area, Baviaanskloof, East London, Hogsback,

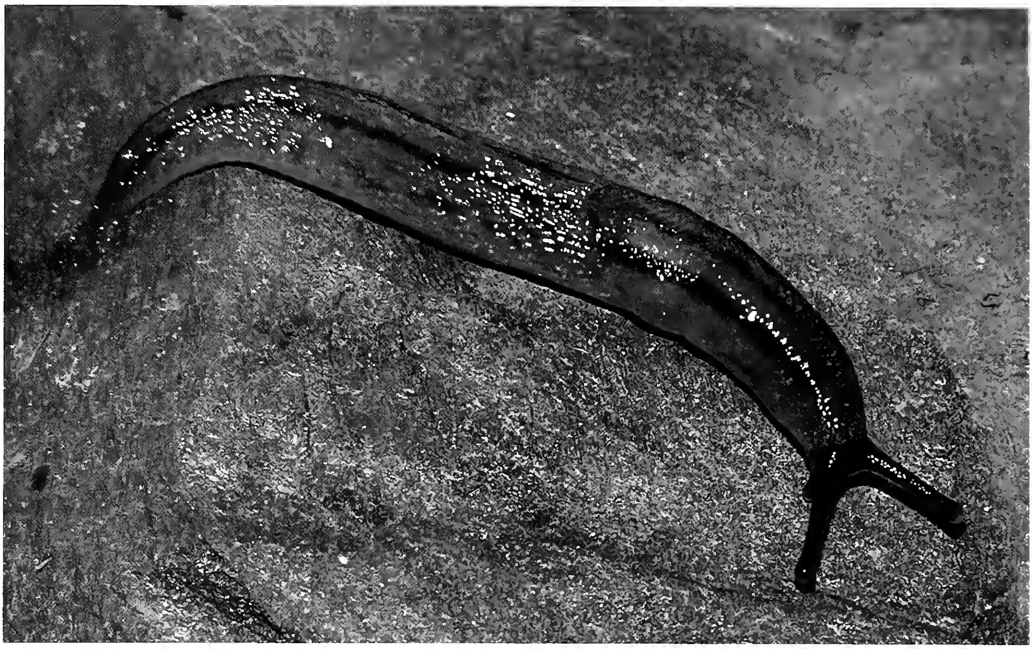
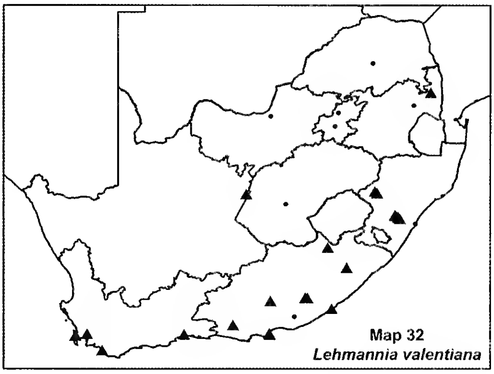


FIGURE 42.—*Lehmannia valentiana* (Férussac, 1822), afrotemperate forest adjacent to fruit orchard, Oubos, Riviersonderend Mountains, W. Cape, length ± 50 mm (NMSA W5753 [2007]).



Langeni, Port Elizabeth and Somerset East), N. Cape (Kimberley), KwaZulu-Natal (Ladysmith area, Hilton and Pietermaritzburg) and Kruger National Park (Skukuza rest camp).

Pest status: Considered a greenhouse pest in northern Europe and North America, damaging orchid flowers and ornamental plants (Chichester & Getz 1969; Mienis 1980; South 1992; Ester *et al.* 2003); not considered a pest in New Zealand (Barker 1999)

Similar indigenous species: None.

Notes: Very similar to and often confused with *Lehmannia marginata* (Müller, 1774), but that species is typically arboreal and has not yet been recorded in South Africa. The growth and reproductive biology of *L. valentiana* has been discussed by Hommay *et al.* (2001), Kano *et al.* (2001) and Udaka *et al.* (2007).

Limacus flavus (Linnaeus, 1758)

(yellow garden slug, yellow cellar slug)

Figure 43

Limax flavus Linnaeus 1758: 652; Collinge 1910: 160; Connolly 1912: 118; 1916: 184; 1939: 176; Barnard 1951: 156; Quick 1952: 188, 1960: 184, pl. 2, fig. 22, text fig. 14; Forcart 1963: 107; Van Bruggen 1964: 162; Herbert 1997: 223, fig. 16; Herbert & Kilburn 2004: 296.

Limax variegatus; Melvill & Ponsonby 1898: 172; Collinge 1900: 2; 1901: 234.

Limax (Limacus) flavus; Altena 1966: 290.

Type loc.: not given, presumed to be Sweden.

Description: A rather striking species with a yellowish ground colour (occasionally salmon-pink), overlain with greyish or greenish mottling, giving the appearance of a grey-green slug with yellow spots; mantle shield similarly patterned; tentacles bluish; no longitudinal

FIGURE 43.—*Limacus flavus* (Linnaeus, 1758), suburban garden, Winterskloof, Pietermaritzburg, KwaZulu-Natal, length ± 82 mm (NMSA V1975 [1995]).

bands on either body or mantle shield; foot sole pale yellow, longitudinally tripartate; body mucus yellow. Extended length 75–100 mm, exceptionally up to 120 mm long.

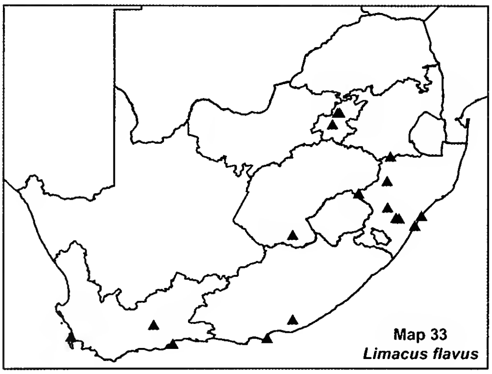
Habitat: Generally synanthropic, occurring mostly in gardens, outbuildings, cellars and kitchens, but also recorded from woodland in Europe (Quick 1960; Kerney & Cameron 1979); in sheltering microhabitats, such as under logs, pots, discarded carpets, sacks and timber. South African material has chiefly been found in gardens and close to human settlements.

Date of introduction: Prior to 1898.

First SA record: Melvill & Ponsonby (1898, as *Limax variegatus*), Pietermaritzburg, KwaZulu-Natal.

Global distribution: Thought to have originated in the Mediterranean (south and western Europe and North Africa). Introduced also to North America (Pilsbry 1948; Dundee 1974; Forsyth 2004), Brazil, Chile and Uruguay (Quick 1952; Stuardo & Vega 1985; Scarabino 2003; Simone 2006), Bermuda (Bieler & Slapcinsky 2000), northern Europe (Kerney 1999), Azores (Backhuys 1975), Madeira (Seddon 2008), St Helena (Gittenberger 1980), Réunion (Stévanovitch 1994; Griffiths & Florens 2006), Madagascar (De Winter 1997), China (Barker 1999), Japan (Kano 2001), Australia and Tasmania (Altena & Smith 1975; Kershaw 1991; Smith 1992), New Zealand (Barker 1979), Hawaii and other Pacific islands (Cowie 1997, 2000).

Distribution in SA (Map 33): Recorded from W. Cape (Cape Town, Ladismith area and



Mossel Bay), E. Cape (Grahamstown and Port Elizabeth), KwaZulu-Natal (Biggarsberg, Durban, Mooi River, Pietermaritzburg, Royal Natal National Park and Umhlali), Free State (Smithfield), Mpumalanga (Wakkerstroom) and Gauteng (Johannesburg and Pretoria).

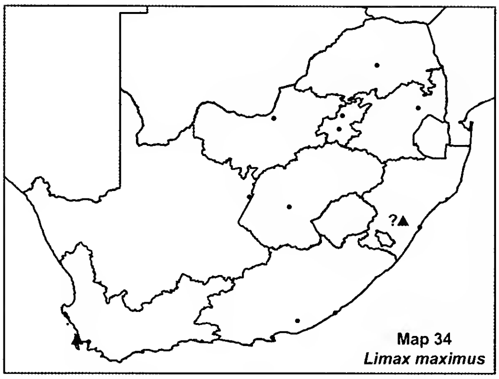
Pest status: Known to damage ornamental plants and market garden vegetables, as well as stored fruit and vegetables (South 1992).

Similar indigenous species: The indigenous urocyclid slug *Elisolimax flavescens* (Keferstein, 1866) is also commonly yellow in colour, but it lacks the greyish green mottling typical of *L. flavus*.

Notes: Cryptic and primarily nocturnal, feeding on decaying vegetation, lichens and

FIGURE 44.—*Limax maximus* Linnaeus, 1758, Newlands Forest, Cape Town, W. Cape, length ± 75 mm (NMSA W5045 [2006]).

fungi, as well as domestic refuse and pet food. May live for several years, and capable of reproduction at near the end of the first year. Fertilisation is normally through out-crossing, but self-fertilisation has been recorded (Evans 1983). Eggs are laid from late summer to winter, juveniles being most common in late winter and spring (Cook & Radford 1988; Barker 1999).



Limax maximus Linnaeus, 1758

(giant garden slug, great grey slug, tiger slug, leopard slug, spotted garden slug)

Figure 44

Limax maximus Linnaeus 1758: 652; Melvill & Ponsonby 1898: 172; Collinge 1901: 229, 234; Connolly 1912: 119; 1916: 184; 1939: 175; Barnard 1951: 156, pl. 20, fig. 10; Quick 1952: 188, 1960: 191, pl. 2, fig. 24; Forcart 1963: 107; Van Bruggen 1964: 162; Herbert 1997: 223, fig. 34; Herbert & Kilburn 2004: 297.

Type loc.: not given, presumed to be Sweden.

Description: A potentially very large slug (extended length up to 200 mm), colour pattern variable, but frequently pale fawn-brown to grey with 2 or 3 longitudinal rows of bold, dark (almost black) spots or blotches on each side of the body, sometimes coalescing into fuzzy bands; mantle shield spotted or marbled with darker coloration, but not banded; head and tentacles uniform pinkish to reddish brown, without bold spots; sole uniformly whitish, tripartate; mucus colourless.

Habitat: Natural woodlands and disturbed habitats, gardens and agricultural land; in sheltering microhabitats, but also climbs walls and trees. Little habitat data is available for South African material, but recently collected samples were found in indigenous forest close to suburbia. Likewise, in New Zealand it has spread beyond suburban areas into exotic plantations and disturbed indigenous habitats (Barker 1999).

Date of introduction: Prior to 1898.

First SA record: Melvill & Ponsonby (1898), Cape Town, W. Cape. Connolly (1916) stated that the species was discovered on Table Mountain above Newlands, by Lightfoot in 1900, but the Melvill & Ponsonby record predated this.

Global distribution: Native to western and central Europe, and perhaps North Africa. Introduced also to the USA (Pilsbry 1948; Chichester & Getz 1969; Branson 1980), Canada (Rollo & Wellington 1975; Forsyth 2004), Brazil (Simone 2006), the Azores (Backhuys 1975), Madeira (Seddon 2008), Canary Islands (Altena & Smith 1975), Eastern Europe and Caucasia (Barker 1999), Japan (Hasegawa *et al.* 2009), Hawaii and other Pacific

islands (Cowie 1997, 2000), Australia (Altena & Smith 1975; Smith 1992), Tasmania (Kershaw 1991) and New Zealand (Barker & McGhie 1984; Barker 1999).

Distribution in SA (Map 34): Recorded only from the W. Cape (Cape Town area) and dubiously KwaZulu-Natal (Pietermaritzburg).

Pest status: Potentially problematic in the domestic and greenhouse horticulture sectors, but rarely identified as a serious pest (South 1992; Barker 2002a)

Similar indigenous species: None.

Notes: Although first recorded in South Africa in the late 1800s, there were no further records of this species in either the Cape Town area or Pietermaritzburg during the 20th century. This was surprising for such a potentially large slug, and suggested that it had not become an established alien. Altena (1996) did not list the species in his discussion of the limacid slugs of South Africa and Sirgel (pers. comm.) has questioned the identity of local records (see Herbert 1997). However, the species has been recently (2006) rediscovered in indigenous forest at Newlands by Dimby Raharinjanahary (University of Cape Town), indicating that the population first discovered by Lightfoot is still extant. This notwithstanding, the lack of further records from Pietermaritzburg, a well-studied area, suggests either that it is no longer living in that area or that the juvenile specimen upon which this record was based (Forcart 1963), was incorrectly identified.

Observations on the reproductive biology, complex mating behaviour and ecology of *L. maximus* can be found in Pilsbry (1948), Runham & Hunter (1970), Barker & McGhie (1984), Tompa (1984) and Cook & Radford (1988). During mating the copulating pairs, with entwined bodies, suspend themselves on a long mucus strand from a branch or other elevated structure. *L. maximus* is an omnivorous species, feeding primarily on decaying plant material and fungi, but will also consume domestic refuse and carrion, as well as ornamental plants, market garden vegetables and horticultural stock, including living plant tissue. Very much a nocturnal slug, with daytime roosts in sheltering microhabitats to which they repeatedly return (Gelperin 1974; Barker & McGhie 1984) and defend aggressively (Rollo & Wellington 1979).

Family: Arionidae Gray, 1840

Small to very large slugs; mantle present as a saddle-shaped shield in mid-anterior region; lacking concentric ridges (cf. fingerprint pattern of Agriolimacidae and Limacidae), instead finely granular; pneumostome on right, anterior to mid-point of mantle shield (instead of posterior to it as in Agriolimacidae, Limacidae and Milacidae); posterior portion of body lacking a longitudinal keel in mid-line; tail rounded and bearing a terminal caudal pit; foot with well-defined fringe, sole not divided into three longitudinal bands; internal shell small to vestigial (reduced to a few chalky granules).

All representatives of the family Arionidae occurring in South Africa are introduced. A number of indigenous genera (*Oopelta*, *Ariopelta* and *Ariostralis*) have traditionally been referred to this family (Sirgel 1985), but these are now considered to represent a distinct family within the Arionoidea, the Oopeltidae (Wiktor *et al.* 2000; Bouchet & Rocroi 2005). This contains two subfamilies both endemic to South Africa, the Ariopeltinae, known only from the Hottentots Holland Mountains (W. Cape) and the Oopeltinae, ranging from the Stutterheim area (E. Cape) through the southern and southwestern Cape to Namaqualand. To date, only two species of Arionidae have been recorded in South Africa, *Arion intermedius* and *A. hortensis*, both originally from Europe, the latter perhaps representing an aggregate of closely related species. They belong to the subgenus *Kobeltia* Seibert, 1873, species of which are generally small, secretive and cryptically coloured, differing little in external characters.

Additionally, other arionid slugs, e.g. *Arion ater* (Linnaeus, 1758) and *A. subfuscus* (Draparnaud, 1805), are known to be adept travellers and have been recorded in North America, Australia and New Zealand. It is quite possible that they may eventually be introduced to South Africa and this should be borne in mind when identifications are made.

Arionid slugs are generally herbivorous, feeding on plant material and fungi, although some may scavenge on waste matter and carrion. When disturbed, many species contract longitudinally such that they become almost hemispherical. With the possible exception of *A. intermedius*, all the arionids mentioned above are potential pest species.

Arion hortensis aggregate Férussac, 1819

(garden arion, Férussac's orange-soled slug, yellow-soled slug)

Figure 45

Arion hortensis Férussac 1819: 65, pl. 2, figs 4–6; Connolly 1939: 183; Barnard 1951: 156, pl. xx, fig. 12; Quick 1952: 188; Forcart 1963: 106; Bruggen 1964: 162.

Type loc.: Paris, France.

non Herbert & Kilburn, 2004: 294 [=*Arion intermedius*].

Description: Small slugs, mostly dark grey, bluish grey or bluish black in colour, but sometimes with a brownish tinge; dorsal area somewhat darker; sides paler with a dark longitudinal line at about mid height, sometimes with a paler 'shadow' band above this; similar bands continue on mantle shield; tentacles reddish (*A. hortensis s.s.*, *A. oweni*) or bluish (*Arion distinctus*); sole of foot yellowish to orange, mucus of similar colour. Extended length usually 25–30 mm, exceptionally 40–50 mm.

Habitat: Occurs in a wide range of habitats in its native range, including woodland, cropland, ruderal habitats and gardens; more subterranean than other *Arion* species (Quick 1960; Kerney 1999). The early South African records cited no habitat data, but recently collected material was obtained in exotic pine plantations.

Date of introduction: Prior to 1939.

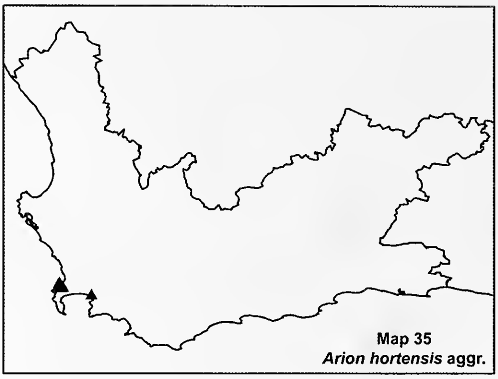
First SA record: Connolly (1939), Newlands, Cape Town, W. Cape.

Global distribution: Native to western Europe. Introduced also to the USA (Pilsbry 1948; Chichester & Getz 1969), Canada (Rollo & Wellington 1975), Madeira (Seddon 2008), St Helena (Crowley & Pain 1977), Sri Lanka (Mordan *et al.* 2003), Tasmania (Kershaw 1991) and New Zealand (Barker 1979, 1999).

Distribution in SA (Map 35): Recorded only from the environs of Cape Town and Stellenbosch. A record from KwaZulu-Natal (Herbert & Kilburn 2004) was based on incorrectly identified material.

Pest status: A potentially serious pest in gardens and agricultural crops (Quick 1960; South 1992; Barker 1999, 2002a), and pasture (Barker 2002b).

FIGURE 45.—*Arion hortensis* aggr., *Arion hortensis* Férussac, 1819, Penllergaer, Swansea, UK, length ± 27 mm (NMSA L7785[2009]).



Similar indigenous species: None.

Notes: I use the name *Arion hortensis* for South African material in its broadest sense. The early South African records for the taxon predate the work of Davies (1977, 1979) who demonstrated that the name *Arion hortensis*, as historically used, relates to a complex of three cryptic species: *A. hortensis* itself, plus *A. distinctus* Mabille, 1868, and *A. owenii* Davies, 1979. An additional species has now been described from Ireland (Anderson 2004). As a result, we cannot now be certain which of these species is represented by these early records. Species discrimination requires experience and it is doubtful that external features can be reliably used for this purpose, since there is overlapping variation. Indeed, Davies herself stated 'the absolute reliability of any of these external distinctions is extremely doubtful . . . ' (Davies 1979). The features diagnostic of the species relate to characters of the distal reproductive tract and spermatophores.

With this doubt surrounding the identity of South African records of *Arion hortensis*,

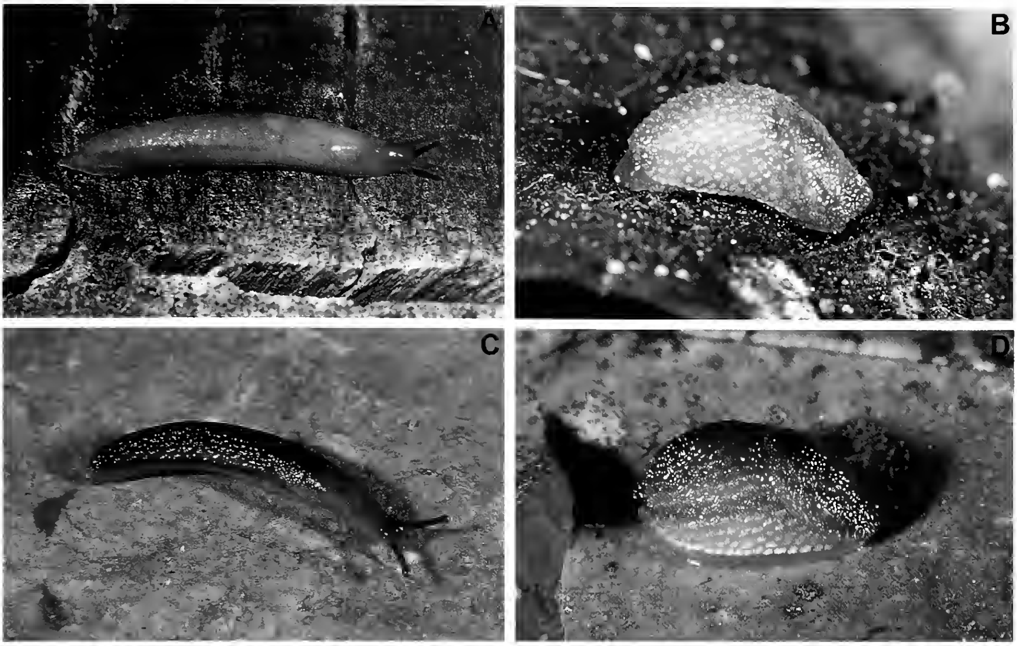
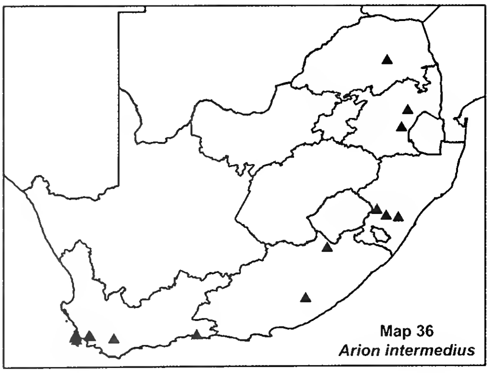


FIGURE 46.—*Arion intermedius* Normand, 1852. A, Halstone Farm, Barkly East, E. Cape, length ± 15 mm (NMSA W6766[2009]); B, contracted specimen showing prickly skin texture, Silvermine Nat. Res., above Boyes Drive, Cape Peninsula, length ± 8.0 mm (NMSA W2475[2004]); C, Highmoor, KwaZulu-Natal (NMSA V9027[2001]; D, Skeleton Gorge, Kirstenbosch, Cape Town, length ± 9.0 mm (NMSA W1472[2004]).

I treat the material as '*A. hortensis* aggr.'. There is good evidence, however, that newly collected material from the Newlands Forest in Cape Town is in fact referable to *Arion distinctus* and this species is thought to be the most proficient traveller within the aggregate (T. Backeljau pers. comm. 2009).

Species within this complex are herbivorous, feeding on fungi, dead plant material, grain seeds and root vegetables, and have an annual life cycle, reproducing primarily by outcrossing (South 1992). Further information on species discrimination within this aggregate can be found in Davies (1977, 1979), De Wilde (1983, 1986), De Winter (1984), Backeljau & Van Beeck (1986), Backeljau & De Bruyn (1990), Backeljau *et al.* (1996), Iglesias & Speiser (2001) and Anderson (2004).



Arion intermedius Normand, 1852

(hedgehog slug, glade slug)

Figure 46

Arion intermedius Normand 1852: 8; Connolly 1912: 127; 1916: 185; 1939: 182; Barnard 1951: 156; Quick 1952: 188; Van Bruggen 1964: 162; Altena 1966: 271; Herbert & Kilburn 2004: 294.

Arion minimus Simroth 1885: 237, 289, pl. 7, fig. 41, pl. 11, figs 18–23. Type loc.: Niederlausitz and Harthwalde, near Leipzig.

Arion fuscus; Collinge 1900: 7; 1901: 235; 1910: 170; Connolly 1912: 126; 1916: 185 (see Connolly 1939: 183, 629).

Arion (Microarion) intermedius; Barker 1979: 416 (further references and synonymy).

Type loc.: Valenciennes, France.

Description: A small slug, extended length up to 20 mm; yellowish white to grey, sometimes with an indistinct longitudinal band on

each side; head and tentacles darker; mucus yellow. When the animal is contracted, the granules on the dorsal surface become exaggerated, resulting in a somewhat prickly appearance.

Habitat: In Europe the habitat preferences of *A. intermedius* are wide, including woodland, heath and pasture as well as acidic habitats and even conifer plantations (Quick 1960; Kerney 1999), but it tends to avoid arable land, gardens and disturbed habitats (South 1992). The limited habitat data available for South African material is consistent with this, the bulk of records being from indigenous habitats in peri-urban areas rather than gardens. In Australia and Tasmania it has spread widely into natural habitats, even those in remote areas (Smith 1998b).

Date of introduction: Introduced to South Africa prior to 1898 (Connolly 1916, as *Arion fuscus*).

First SA record: Collinge (1900, as *Arion fuscus*), Cape Town, W. Cape [Lightfoot].

Global distribution: Native to western Europe. Introduced also to the USA (Pilsbry 1848; Chichester & Getz 1969), Canada (Rollo & Wellington 1975; Forsyth 2004), Chile (Cádiz & Gallardo 2007), Columbia (Hausdorf 2002), Madeira (Seddon 2008), Réunion (Stévanovitch 1994; Griffiths & Florens 2006), Sri Lanka (Naggs *et al.* 2003), Australia and Tasmania (Smith & Kershaw 1979; Kershaw 1991), New Zealand (Barker 1979, 1999), Hawaii (Cowie 1999) and Tahiti (Quick 1960).

Distribution in SA (Map 36): Recorded from W. Cape (Cape Town, Cape Peninsula, Riviersonderend Mountains, Stellenbosch and Knysna), E. Cape (Barkly East area, Hogsback), KwaZulu-Natal (Dargle, Giant's Castle Game Reserve, Pietermaritzburg), Limpopo (Tzaneen area) and Mpumalanga (Lydenburg and Nelspruit areas).

Pest status: Has been reported to occur in large numbers in winter wheat crops in Britain (South 1992), but its significance as a pest is not clear. In New Zealand, Barker (1999) stated that it may not achieve pest status, but nonetheless cited it as a species of concern in pasture (Barker 2002b).

Similar indigenous species: None.

Notes: Barker (1999) reported the species to have an annual life cycle, with eggs being laid in late summer and autumn (Quick 1960). The normal mode of reproduction is by self-fertilisation or parthenogenesis (South 1992). Herbivorous and often associated with fungi (Quick 1960). The tendency for this species to invade natural habitats in regions to which it is introduced is noteworthy (Chichester & Getz 1969; Barker 1999).

Excluded species

Acanthinula aculeata (Müller, 1774) (Valloniidae): Sirgel (1979) recorded this W. Palaearctic species from remote, natural habitat in the Kruger National Park and speculated that it had been introduced there by human agency. Although alien terrestrial molluscs are recorded in the Kruger National Park (Van Bruggen 1966, 1968), I consider it unlikely that this *Acanthinula* material was introduced. More probably, the material is of an indigenous African species, but the taxonomy of this genus of minute snails and the distribution of its constituent species in Africa is extremely poorly known. At least two unrecorded and possibly undescribed species have been found in KwaZulu-Natal and the E. Cape, one a low altitude tropical/subtropical species (identical to Sirgel's material), the other afrotemperate, both in association with natural habitats and both almost certainly indigenous.

Achatina aurora Pfeiffer, 1855 (Achatinidae): Although described from 'Natal' (evidently Durban) Connolly (1912, 1916) considered this name to be based on a dead, beach worn shell of a West African species, probably brought in with ship ballast. More probably, since the specimen concerned came from the Hugh Cuming collection, the provenance given was erroneous (Dance 1986). Mead (2004) stated that the worn holotype resembled an immature specimen of the W. African *Archachatina purpurea* (Gmelin, 1790).

Granopupa granum (Draparnaud, 1801) (Chondrinidae): Verdcourt (1963) recorded this Mediterranean species from 'Aleudia', Transvaal, South Africa. However, this local-

ity cannot be localised and the record has since been shown to have been based on mislocalised specimens (Van Bruggen 1973).

Pupisoma orcula (Benson, 1850) and *P. japonicum* Pilsbry, 1902 (Valloniidae): Connolly (1916) included both these species in his list of terrestrial molluscs introduced to South Africa, but both are now thought to be indigenous (Van Bruggen & Appleton 1977; Herbert & Kilburn 2004), with circum-tropical and Afro-Asian distributions respectively. Wide distributions in such minute snails are not infrequent. *P. orcula* is now thought to be a junior synonym of *P. dioscoricola* (C.B. Adams, 1845) (*fide* Hausdorf 2007) and *P. japonicum* may be the same as *P. harpula* (Reinhardt, 1886), but the latter synonymy requires further study.

Pupoides coenopictus (Hutton, 1834) (Pupillidae): This N. African–S. Asian species was recorded from Jansenville, E. Cape, by Pilsbry (1921, in 1920–21), but Connolly (1939) subsequently questioned the record, believing it to be based on wrongly identified specimens of the indigenous *Pupoides calaharicus* (Boettger, 1886), which is common and widespread in the drier parts of southern Africa.

South African species occurring elsewhere

South Africa now has a total of 34 confirmed alien terrestrial molluscan species, but the same phenomena through which this exotic fauna derives, have led to the introduction of a number of indigenous South African species to other parts of the world, or to their interception at foreign ports of entry. Few of these, however, are recognised as regularly intercepted travelling species (Robinson 1999). Some examples include:

Achatina immaculata (Lamarck, 1822) [= *A. panthera* Férussac, 1832] (Achatinidae)—native to tropical and southeastern Africa, introduced to Madagascar (Griffiths & Herbert 2008), Comoros (Bequaert 1950), Mascarene Islands (Griffiths & Florens 2006) and Seychelles (Gerlach 2006).

Elisolimax flavescens (Keferstein, 1866) (Urocyclidae)—native to the eastern southern Africa, intercepted by US quarantine officials on orchid plants (Robinson 1999 and in lit. 2009). Potentially pestiferous (Bedford 1978; De Jager & Daneel 2002), particularly on bananas. This species has been flagged as being of quarantine concern in the USA (Cowie *et al.* 2009).

Fauxulus capensis (Küster, 1841) (Orculidae)—native to the southern Cape, intercepted by US quarantine officials (Robinson 1999, evidently on cut *Protea* flowers).

Gulella sp. (Streptaxidae)—reportedly from South Africa, intercepted by US quarantine officials (Robinson 1999).

Gulella wahlbergi (Krauss, 1848) (Streptaxidae)—endemic to KwaZulu-Natal, deliberately introduced to Hawaii for biocontrol of *Achatina fulica* and thought to have become established by 1972, but may have since disappeared (Cowie 1997). Since *G. wahlbergi* is a scarce, narrow-range endemic (Herbert & Kilburn 2004), the original identification of the material exported to Hawaii must be considered dubious. It may perhaps have been the similar and very much more common *G. adamsiana* (Pfeiffer, 1859).

Laevicaulis alte (Férussac, 1821) (Veronicellidae)—native to Central and East Africa southwards to KwaZulu-Natal, introduced to many other tropical regions including the USA (Neck 1992; Robinson 1999), Bermuda (Gomes & Thomé 2004), the Mascarene Islands (Griffiths & Florens 2006), Hong Kong (Brandt 1980), India (Raut & Mandal 1984), Sri Lanka (Mordan *et al.* 2003), Southeast Asia (Gomes & Thomé 2004), Australia (Smith 1992), New Caledonia (Solem 1964), Hawaii (Cowie 1997) and islands in the south Pacific (Cowie 2000). It is a significant agricultural pest in India (Raut & Mandal 1984) and Sri Lanka (Mordan *et al.* 2003), and a recognised travelling species (Smith 1989).

Natalina cafra (Férussac, 1821) (Rhytididae)—native to E. Cape and KwaZulu-Natal, deliberately introduced for the purposes of pest control to Hawaii (Mead 1979) and Bermuda (Bieler & Slapcinsky 2000), but has evidently not become established at either locality.

Trachycystis capensis (Pfeiffer, 1841) (Charopidae)—endemic to the southern Cape, intercepted on bouquets of mixed cut flowers in 1999 by US quarantine officials (Robinson in lit. 2009).

Trachycystis menkeana (Pfeiffer, 1842) (Charopidae)—endemic to the south-western Cape, intercepted by US quarantine officials on cut flowers (*Leucodendron* spp.) (Robinson in lit. 2009).

Trachycystis sabuletorum (Benson, 1851) (Charopidae)—endemic to the southwestern Cape, intercepted by US quarantine officials (Robinson 1999).

Urocyclus kirkii Gray, 1864 (Urocyclidae)—endemic to southeastern Africa, intercepted on *Strelitzia nicholai* propagation stock by US quarantine officials (Robinson in lit. 2009).

Potential future introductions

Although it is certain that further non-native species will in time be introduced to South Africa (cf. Figure 3), it is of course impossible to predict which species these will be. Robinson (1999) cited an astonishing total of 4 900 interceptions of non-marine marine gastropods at US ports of entry during the 5-year period 1993–1998. This included 330 terrestrial species. He further provided a list of 131 species of terrestrial mollusc that are known to be proficient travellers. Climatic and environmental conditions in South Africa will clearly not be suitable for some of these species, but when considering candidate species with potential for introduction and establishment in South Africa, it is logical to look first at these known 'hitch-hikers', particularly those that are already known to be successful colonisers in regions with climatic conditions similar to those prevailing in South Africa. If a species has proven to be good invader in one place, it may well be in another (Ruesink *et al.* 1995).

Given that the translocation of species from one part of the world to another is an inescapable result of international trade and transport, it is essential that we attempt to identify the species of primary concern. Although all introductions should ideally be avoided, many may in reality be of little real consequence. Others, however, represent varying degrees of threat as potentially invasive species with considerable environmental and/or economic significance. I give below some examples of terrestrial molluscs that fall in to this category from a South African perspective. These are mainly species of European/Mediterranean origin for which climatic conditions in South Africa, particularly in the southern and western Cape, are likely to be favourable. They are known to be proficient travellers and are recognised to be significant pests in other regions to which they have been introduced, notably in southern Australia. In addition to these, I mention again *Otala punctata* and *Rumina decollata*, two species already discussed, which were introduced to South Africa and subsequently eradicated, yet which could easily be re-introduced. It is important that pest risk assessments be conducted for these species and that quarantine officials and phyto-sanitary inspectors at ports of entry be able to identify them. An number of tropical and subtropical species are also mentioned in reference to the eastern seaboard of South Africa.

Family: Cochlicellidae Schileyko, 1972

Cochlicella acuta (Müller, 1774)

Figure 47

Helix acuta Müller 1774: 100.

Type loc.: Italy.

Description: Similar to *Cochlicella barbara* described above, but noticeably more elongate and attaining a larger size; up to 18 mm long, rarely more.

Notes: Native to western Europe and the Mediterranean, this species has been introduced to southern Australia where it is considered a significant pest. This is due not so much to its feeding habits but to its aestivation behaviour (cf. *Theba pisana* above), resulting in the clogging of harvesting equipment and contamination of the grain (Baker 1986, 1989, 2002; Baker *et al.* 1991). It has the potential to spread widely in the southern and western Cape in a manner similar to *C. barbara*.

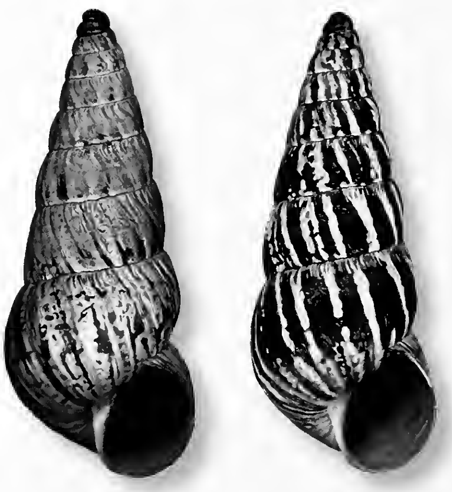


FIGURE 47.—*Cochlicella acuta* (Müller, 1774), Yorke Peninsula, South Australia, pale specimen, length 14.0 mm; dark specimen, length 12.7 mm (NMSA L5505 [2000]).

Family: Hygromiidae Tryon, 1866

Cernuella virgata (Da Costa, 1778)

Figure 48

Helix virgata Da Costa 1778: 79, pl.4, fig. 7.

Type loc.: England, several localities cited in original description.

Description: A variable species in terms of shape and coloration; similar to *Theba pisana* (see above), from which it differs in having a wider umbilicus and in lacking the fine spiral lirae that give *T. pisana* a microscopically reticulate sculpture; in *C. virgata* the shell bears only subsutural axial pliculate and growth-lines. Whorls evenly rounded and periphery more or less at mid-whorl. Shell uniformly white or pale ginger-brown, commonly with brown spiral bands or lines; interior of outer lip with a more distinct subterminal thickened rib than *T. pisana*, and frequently tinged with brown (not pink). Diameter usually less than 20 mm, rarely up to 25 mm.

Notes: *Cernuella virgata* is another common travelling species of Mediterranean–European origin (Kerney *et al.* 1983). It feeds primarily on decaying plant material, but is also known to eat green plant tissue (Butler 1972). The species has been introduced to southern Australia where it is now widely distributed and considered a significant pest of seedlings in general, cereal crops, legume-based pastures and ornamental plants (Baker 1986, 1988b, 1989, 1996, 2002). Baker (2002) recorded *C. virgata* densities of over 400/m^2 in barley-pasture rotation in climatically favourable years in South Australia. Like *Theba pisana* and *Cochlicella acuta*, it aestivates on the stalks and heads of cereal crops resulting in the clogging of harvesting machinery and contamination of the grain, such that the crop is down-graded or rejected at point of sale (Baker 2002). Contaminated export shipments have also been rejected by quarantine inspectors (Baker 1989). May serve as an intermediate host for *Brachylaima* trematode parasites of poultry, some of which have also been reported to infect humans (Spratt 2005), and similarly for dicrocoeliid trematodes of sheep and goats (Otranto & Traversa 2002). In a recent survey of alien terrestrial slugs and snails of priority quarantine concern in the USA, hygromiid snails ranked highly and *C. virgata* highest of all (Cowie *et al.* 2009).

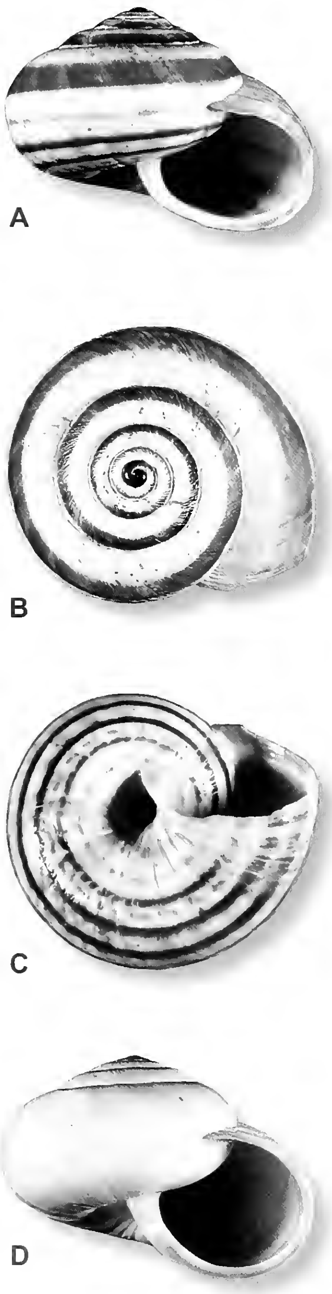


FIGURE 48.—*Cernuella virgata* (da Costa, 1778), Avignon, France; A–C, diameter 16.2 mm (NMSA K6677); D, diameter 16.4 mm (NMSA J7063).

Microxeromagna lowei (Potiez & Michaud, 1838)

Figure 49

Helix lowei (*non Helix lowii* Férussac, 1835) Potiez & Michaud 1838: 91.

Helix (Xerophila) armillata Lowe 1852: 113 [*nom. nov.* for *Helix lowei* (*non Helix lowii* Férussac, 1835) Potiez &Michaud 1838].

Helix vestita Rambur 1868: 267.

Type loc.: Madeira.

Description: Shell small, lenticular; sculptured with irregular, close-set, axial riblets and with sparse periostracal hairs; umbilicus moderately wide; ground colour brownish, patterned with irregular whitish markings, frequently in the form of broad whitish axial bands on apical surface and spiral bands on base. Diameter up to 7.0 mm.

Notes: A Mediterranean species which has been introduced to southeastern Australia. While the snail itself is of limited concern as a crop pest, it is considered a contamination risk in citrus cargo. As a result, shipments of citrus fruit in which the snail is found are likely to be quarantined by phytosanitary inspectors, particularly in the USA, who may either deem it necessary to destroy or re-export the cargo. The species can occur at high densities (up to 4 000 m^{-2}) in the leaf litter beneath citrus trees and will also climb into the tree canopy and aestivate in the navels of oranges. Further information on the habitat requirements, reproductive biology and control of the species (as *M. armillata*), and its significance to the Australia citrus industry can be found in the following references: Kerney *et al.* (1983); Hausdorf (1990); Lush (1999, 2007); Zhao *et al.* (2004). Since citrus crops constitute an important export product in South Africa, this snail could have significant economic implications should it be introduced here. The Mediterranean climate of the W. Cape would almost certainly provide favourable conditions for its establishment. Smith (1992) recorded *Microxeromagna* from South Africa, but the basis for this record is not known.

Another Mediterranean snail, *Xerotrichia conspurcata* (Drapanaud, 1801), closely resembles *Microxeromagna lowei*, but differs in having fewer, longer periostracal hairs (Clerx & Gittenberger 1977). This was once intercepted in Cape Town on fruit imported from Spain (W. Sirgel pers. comm.).

FIGURE 49.—*Microxeromagna lowei* (Potiez & Michaud, 1838), between Nangiloc and Colignan, Victoria, Australia, in citrus orchard (don. A. Lush), diameter 7.0 mm (NMSA L5529 [2001]).

Family: Subulinidae Fischer & Crosse, 1877

More than a dozen species in this diverse family are recognised travellers (Robinson 1999) and many tropical species have succeeded in establishing themselves in areas far beyond their native range, particularly so as greenhouse aliens in temperate regions (Kerney & Cameron 1979; Horsák *et al.* 2004), but also as invasive species in tropical regions (Cowie 1997). Pilsbry (1906–7) considered *Allopeas gracile* (Hutton, 1834) to be the most widely distributed snail in the world. In addition to *Subulina octona* and *Rumina decollata* discussed above, further adept travelling and colonising subulinids include: *Allopeas clavulinum* (Potiez & Michaud, 1838), *A. micra* (d'Orbigny, 1835), *Leptinaria*

lamellata (Potiez & Michaud, 1838), *Opeas hannense* (Rang, 1831) and *Paropeas achatinaceum* (Pfeiffer, 1846). However, although there is some evidence that subulinids damage the roots of greenhouse plants (Kerney & Cameron 1979), they seem to be rarely cited as significant pests. Nevertheless, in tropical regions they can occur in high densities in natural habitats into which they have dispersed and may possibly out compete indigenous snails (Cowie 2001b, c).

The family includes many poorly defined genera and the species are frequently very similar in shell form, rendering identification difficult. The situation is complicated by the fact that there are ± 57 species of subulinid indigenous to South Africa, which need to be considered when determining whether or not subulinid material is exotic. Nonetheless, the long, narrow shells characteristic of many subulinds (see *Subulina octona* above) are relatively easy to identify to family and all such interceptions at points of entry should be considered matters of quarantine concern. The northeastern coastal regions of South Africa are likely to provide suitable conditions for the establishment of a growing number of travelling subulinids from tropical and subtropical regions.

Family: Succineidae Beck, 1837

Succineid snails are frequently intercepted by US quarantine officials and considered contaminants of horticultural products (Robinson 1999). There is also increasing evidence that they are common alien inhabitants of greenhouses and horticultural nurseries (Schüder *et al.* 2003; Holland & Cowie 2006; Hayes *et al.* 2007). These snails, however, are extremely difficult to identify, particularly if there is no indication of their origin, and the use of DNA data may be the only reliable means to achieve this. The European *Succinea putris* (Linnaeus 1758) is a recognised travelling species (Robinson 1999) and others such as *S. horticola* Reinhardt, 1877, *S. tenella* Morelet, 1865 and *S. costaricana* Martens, 1898 are known to have established populations beyond their native range. Although they may be abundant in horticulture enterprises, it is not yet clear what their impacts are and whether these are significant (Cowie *et al.* 2009). This notwithstanding, Cowie *et al.* (2009) considered the family as a whole to be a significant pest risk in the USA, and the European *Oxyloma elegans* Risso, 1826 (Figure 50) is a recognised pest of ornamental plants in greenhouses and polythene tunnels

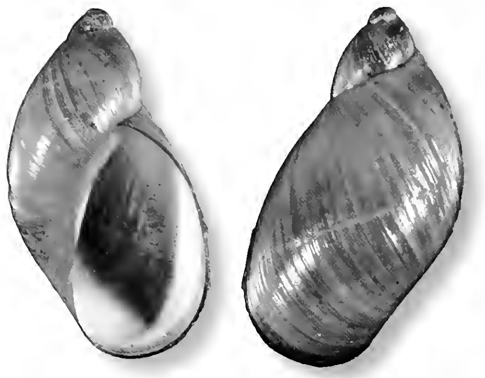


FIGURE 50.—*Oxyloma elegans* (Risso, 1826), Oberbayern, Germany, length ±9.7 mm (NMSA G9338).

(Schüder *et al.* 2003, as *Oxyloma pfeifferi*). Many species have the capacity to self-fertilise. Specimens of an unidentified species of *Oxyloma* have been found in nurseries in the western Cape and although these may represent the indigenous *Oxyloma exarata* (Krauss, 1848), the possibility that they are an introduced species needs to be investigated.

Family: Veronicellidae Gray, 1840

***Sarasinula plebeia* (Fischer, 1868)**

Figure 51

Vaginulus plebeius Fischer 1868: 145.

Type loc.: New Caledonia.

Originally described from New Caledonia, this species has spread widely in tropical and subtropical regions and is considered a significant pest, particularly of bean crops, and perhaps to a lesser degree of bananas, coffee, peppers and tomatoes (Rueda *et al.* 2002). Together with other members of this largely tropical slug family (± 100 species), this species has the potential to become established along the subtropical northeastern seaboard of South Africa. It is evidently surprisingly cold-tolerant (Naranjo-Garćia *et al.* 2007). Species identification is not easy and there are two similar indigenous species, *Laevicaulis natalensis* (Krauss, 1848) and *L. alte* (Férussac, 1821) with which it might be confused. However, as a family, veronicellid

slugs are characteristic and all interceptions at ports of entry should be quarantined and investigated. *Sarasinula plebeia* and *Veronicella cubensis* (Pfeiffer, 1840) are recognised as species of high quarantine importance in the USA (Cowie *et al.* 2009).

FIGURE 51.—*Sarasinula plebeia* (Fischer, 1868) Martinique, Windward Islands, Caribbean, length ± 80 mm (photo courtesy of D. Robinson USDA, APHIS).

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APPENDIX

Distribution of alien snails and slugs in terms of the nine provinces in South Africa.

Species	W. Cape	E. Cape	KZN	Gauteng	N. Cape	Free State	NW. Province	Mp'langa	Limpopo	No. of provinces
Achatina fulica			X							1
Aegopinella nitidula	X									1
Arion hortensis aggr.	X									1
Arion intermedius	X	X	X					X	X	5
Bradybaena similaris			X							1
Cochlicella barbara	X	X			X	X				4
Cochlicopa cf. lubrica	X	X	X	X		X	X			6
Cochlicopa cf. lubricella	X	X		X			X			4
Cornu aspersum	X	X	X	X	X	X	X	X	X	9
Deroceras laeve	X	X	X					X	X	5
Deroceras panormitanum	X	X		X						3
Deroceras reticulatum	X	X	X			X				4
Discus rotundatus	X	X								2
Eobania vermiculata	X	X			X		X			4
Hawaiia minuscula		X								1
Lauria cylindracea	X									1
Lehmannia nyctelia	X	X	X			X				4
Lehmannia valentiana	X	X	X		X			X		5
Limacus flavus	X	X	X	X		X		X		6
Limax maximus	X		X							2
Milax gagates	X	X	X							3
Otala punctata	X									1
Oxychilus alliarius	X	X	X	X		X				5
Oxychilus cellarius	X	X		X	X					4
Oxychilus draparnaudi	X	X		X	X					4
Rumina decollata	X	X								2
Subulina octona	X									1
Testacella maugei	X									1
Theba pisana	X	X			X					3
Vallonia costata		X		X			X			3
Vallonia pulchella	X	X	X	X		X				5
Vitrea contracta	X									1
Vitrea crystallina	X									1
Zonitoides arboreus	X	X	X	X	X		X			6
Province total	**30**	**23**	**15**	**11**	**8**	**8**	**6**	**5**	**3**	

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Family names in upper case. Synonyms and earlier combinations in italics

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